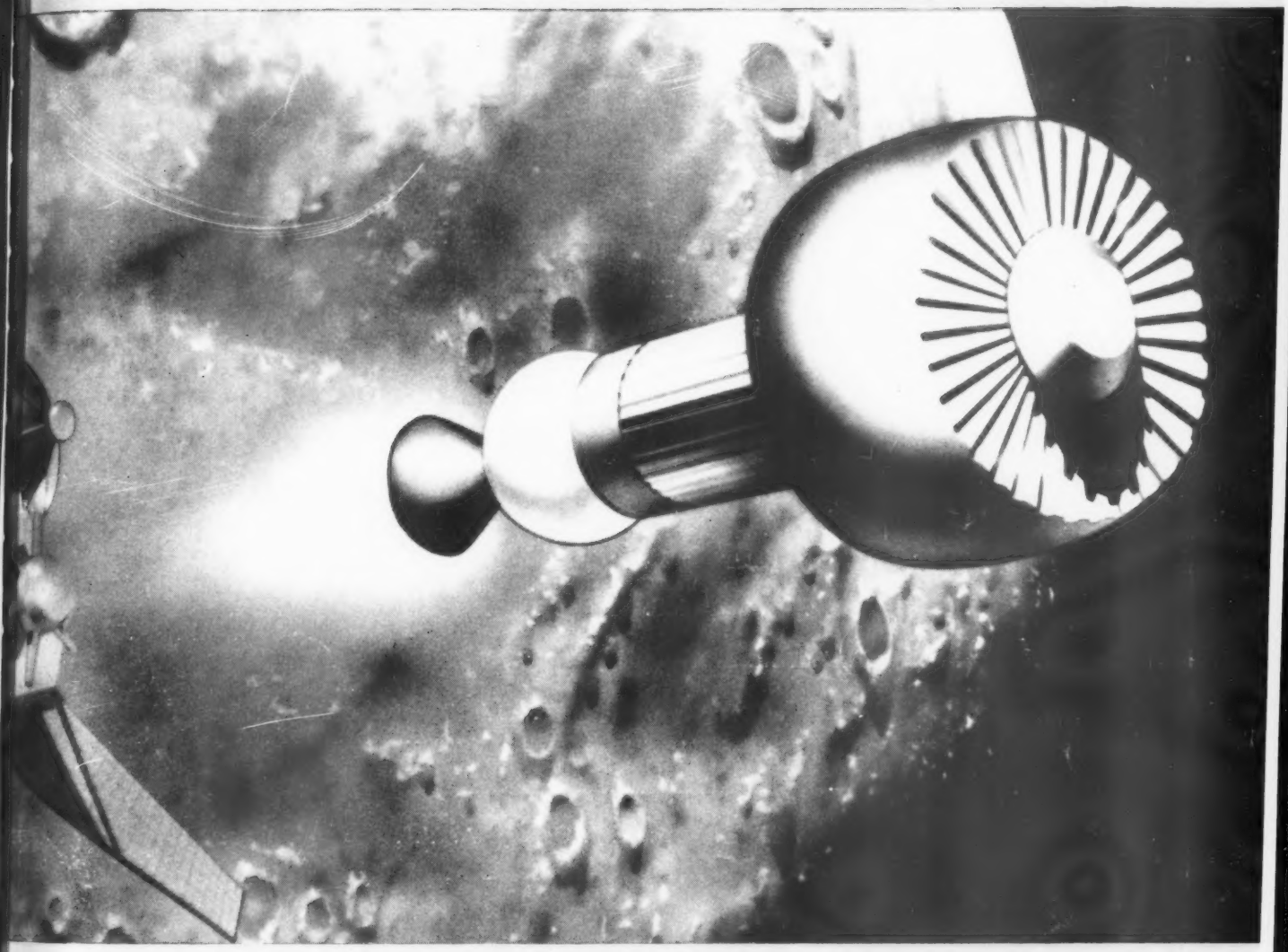
UNIVERSITY OF MICHIGAN
OCT 14 1960
ENGINEERING LIBRARY



VOL. II No. 8

CONTENTS

OCTOBER 1960

	Page
ATOMS AND SPACE. Hugh L. Dryden	226
SPUTNIK IV	230
NEW SOVIET SPACE-BOOSTER	231
THE SATURN PROJECT	232
MOON-LANDING PROBE	234
PHILATELIC SAFARI. Donald Malcolm	235
CORRESPONDENCE	236
NEW EVIDENCE OF MARTIAN LIFE. Michael H. Briggs	237
SHAPING THE SPACE-PROGRAMME	239
CO-OPERATION IN SPACE-RESEARCH. Arnold W. Frutkin	247
REVIEWS	252
ROCKETDYNE'S MAMMOTH F-1	253
QUESTION AND ANSWER	254
SATELLITE MODEL RE-ENTRY	254
THE N.A.S.A. SPACE-SCIENCES—4	255
ATOMIC GENERATOR FOR SPACECRAFT	260

THE BRITISH INTERPLANETARY SOCIETY

Society for the promotion of the science and technology of aerospace and astronautics.
A founder member society of the International Astronautical Federation.

(Founded 1933)

12, Bessborough Gardens, London, S.W.1.

Telephone: TATe Gallery 9371. Telegrams: Britintsoc, Souwest, London.

COUNCIL AND OFFICERS, 1959-1960

PRESIDENT

L. R. SHEPHERD, B.Sc., Ph.D.

VICE-PRESIDENTS

K. W. GATLAND, F.R.A.S. W. R. MAXWELL, B.Sc., Ph.D.

ORDINARY MEMBERS OF COUNCIL

J. E. ALLEN, B.Sc. (Eng.), A.M.I.Mech.E., A.F.R.Ae.S., A.F.I.A.S.
M. BRENNAN, B.Sc., M.I.Mech.E., F.R.Ae.S.
A. H. S. CANDLIN, B.Sc.(Tech. Chem.), Assoc.I.Mech.E.
D. J. CASHMORE, M.Sc.
M. N. GOLOVINE, M.B.E., A.C.G.I., A.F.R.Ae.S.
S. W. GREENWOOD, B.Sc., M.Eng., A.M.I.Mech.E., A.F.R.Ae.S.
D. HURDEN, B.A., G.I.Mech.E.
N. H. LANGTON, M.Sc., Ph.D., A.M.Brit.I.R.E., A.Inst.P.
N. R. NICOLL.
A. E. SLATER, M.A., M.R.C.S., L.R.C.P., F.R.Met.S.
E. T. B. SMITH, B.Sc., D.C.Ae., A.M.I.Mech.E., A.F.R.Ae.S.
G. V. E. THOMPSON, B.Sc., B.Sc.(Eng.), A.R.C.S., F.R.I.C., A.I.L., L.I.M.

SECRETARY: L. J. CARTER, A.C.I.S.

BRANCH SECRETARIES

Midlands: G. C. HAEFELI, B.Sc., A.M.I.Mech.E., 960 Bristol Road, Selly Oak, Birmingham, 29.
North-Western: P. L. SOWERBY, Flat 2, 15 The Beeches, West Didsbury, Manchester, 20.
Scottish: D. MALCOLM, 42 Garry Drive, Paisley, Renfrewshire.
Western: R. SYKES, B.Sc.(Eng.), A.C.G.I., 21 Mackie Grove, Filton, Bristol.
Yorkshire: Miss DOROTHY DYSON, M.P.S., 5 Harker Terrace, Old Road, Stanningley, Pudsey, Yorkshire.

SECRETARIES OF INFORMAL GROUPS

Derby: D. A. WIGLEY, 160 Manor Road, Derby.
South Shields: W. DEVINE, 145 Bamburgh Avenue, South Shields.
Washington, D.C.: FREEMAN G. LEE, 7302 Keene Mill Road, Springfield, Va., U.S.A.

SPACEFLIGHT

Volume II October 1960 Number 8

THE MAGAZINE OF AEROSPACE SCIENCE AND TECHNOLOGY

Editor
KENNETH W. GATLAND, F.R.A.S.

Editorial Board
M. F. ALLWARD
C. A. CROSS, M.A., F.R.A.S.
D. HURDEN, B.A., GRAD. I. MECH. E.
A. E. SLATER, M.A., M.R.C.S., L.R.C.P., F.R.MET.S., F.Z.S.

Correspondence and manuscripts intended for publication should be addressed to the Editor at 42, Knightwood Crescent, New Malden, Surrey.

Opinions in signed articles are those of contributors, and do not necessarily reflect the views of the Editor, the Editorial Board or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

All material is protected by copyright. Responsibility for security clearance, where appropriate, rests with the author.

***Spaceflight* is published quarterly by the British Interplanetary Society, and is issued free to members.**

Full particulars of membership of the British Interplanetary Society may be obtained from the Secretary. The secretarial address is 12, Bessborough Gardens, London, S.W.1; telephone TATe Gallery 9371.

***Spaceflight* is distributed in North America by Sky Publishing Corporation, Harvard College Observatory, Cambridge 38, Mass., U.S.A. All enquiries concerning subscriptions and single copies should be sent to Sky Publishing Corporation.**

COVER:

Now under construction at the Jet Propulsion Laboratory, Pasadena, is a spacecraft designed to deposit instruments in working order on the Moon. This artist's impression shows the small 300 lb. instrument capsule—having separated from the carrier vehicle—at the moment of firing its retro-rocket some 20 miles above the lunar surface. *(See article, page 234.)*

National Aeronautics and Space Administration

Triumph of Sputnik V

Another milestone in astronautics has been reached by the Russians. On 19 August, it is believed from Aralsk, near the Aral Sea, a multi-stage rocket was launched carrying a payload of over 4½ tons in the shape of a two-part spacecraft which entered a near-circular orbit with an apogee of about 210 miles and a perigee of some 190 miles. The vehicle contained a varied "cargo" comprising two dogs, 40 mice and two rats, fruit flies, plants and fungi, microscopic water plants and some seeds. There were also instruments for measuring light and heavy nuclei in primary cosmic rays, ultraviolet radiation from the Sun, and the amount of cosmic radiation in the pressurized animal container.

Inside the spacecraft, television was used for the first time to observe the reactions of the test-animals in orbit.

The climax to this remarkable experiment came more than 24 hours later when, on a command signal from the ground, a retro-rocket fired to slow down the spacecraft and cause it to re-enter the atmosphere. At this point, the vehicle was on its 18th orbit and had travelled nearly 500,000 miles. *Tass* reported that the spacecraft "was provided with a special thermal shield and passed safely through the Earth's atmosphere". It was also said that the bio-capsule was catapulted clear of the spacecraft as a safety measure after re-entry and that both made successful landings some 6¼ miles from the designated point in an undisclosed region of the U.S.S.R.

Although it will be some time before all the results of this historic experiment have been analysed, the next step of substituting a man, or possibly two men, for the animals cannot be too far away. With so much achieved, it would be logical to suppose that the Russians are on the verge of launching men on short-range ballistic flights in rockets similar to those which have previously carried dogs to heights of between 100 and 300 miles. Indeed, they may have already done so!

On page 230, readers will find an account of the Sputnik IV experiment which preceded the events of 19–20 August, which will help to piece together some of the technical details of the basic spacecraft, although much still remains obscure.

In the January, 1961, issue will be found a fully illustrated report on the 11th I.A.F. Congress in Stockholm as well as more details of Sputnik V. We are pleased to announce that from January, ***Spaceflight*** will be published bi-monthly instead of quarterly, a measure which, among other things, should help us provide a more complete and up-to-date coverage of the astronautical news.

PRINTED IN GREAT BRITAIN

Atoms and Space

By HUGH L. DRYDEN*

This scheme by Krafft Ehricke of Convair Astronautics show show nuclear-energy may be used to launch heavy payloads (22,000 lb.) directly to the Moon, without the need of orbital refuelling. Delta-wing booster vehicle (lower right) is detached outside the atmosphere to glide back to Earth. Gondola, containing astronauts, unreels cable to assume a position 1000 ft. behind nuclear-powered upper stage to reduce radiation hazard. Crew would use remote controls to start nuclear rocket engine, fed with liquid hydrogen.

Convair Astronautics

Introduction

The stated subject of this paper is so broad that it might include everything from the study of the infinitely small recesses of the atom to the vast infinity of galactic space. We will therefore begin by limiting the scope of the subject to a discussion of three questions: (1) What are the potentialities of the use of nuclear energy in the exploration of space? (2) What uses of nuclear energy in space exploration are expected in the next decade? (3) What is likely to be the impact of space exploration on the development of other applications of nuclear energy?

We will discuss these questions in relation to the space activities of the United States as set forth in the National Aeronautics and Space Act of 1958 and in the programmes of the National Aeronautics and Space Administration, the agency established by Congress to carry out the policy, established in that Act, that activities in space should be devoted to peaceful purposes for the benefit of all mankind. Such activities include at present the exploration of space to gain greater knowledge and understanding of the Earth and its atmosphere, the Moon, planets, and the Universe; the application of available knowledge to develop capabilities for other activities in space for the benefit of mankind; and the beginning of the exploration of space by man himself.

A programme of this magnitude must be reinforced by a broad programme of research and development in many fields of technology and by vigorous development of advanced technology at the frontiers of knowledge. The most visible aspects of the programme are, however, the actual flight missions of space vehicles. Current missions include those connected with scientific measurements in sounding rockets and Earth satellites, lunar and interplanetary missions, meteorological satellites, passive communications satellites, and missions leading to manned satellite flight. As we look down the road we see more advanced missions, including hard and soft landings on the Moon and planets, orbiting astronomical laboratories, circumlunar flights by man, landing of man on the Moon and return, etc.

Whatever the mission, we find that propulsion systems are the key to possible accomplishment, whatever the specific objectives. We find now to our regret that we do not have propulsion systems required for the payloads for many of the missions we need to undertake. In fact we are unable to carry out many missions because we do not have the thrust required to carry available precise guidance systems in the final stage and hence cannot perform those missions requiring precise guidance.

Our present capability has been further limited by the unavailability of upper stage rockets of the proper sizes to match the capabilities of the intercontinental missile

** Deputy Administrator, National Aeronautics and Space Administration.*

boosters available for use as the first stage of a space vehicle. We have been compelled to use available rockets from the Vanguard satellite or other missile programmes.

Energetic steps are being taken to develop as quickly as possible the required propulsion and vehicle capabilities, including optimized stages for the Atlas and Thor and new rocket engines with a thrust exceeding 1 million lb. Although these early developments are based on chemical fuels, attention has also been given to nuclear fuel.

Applications of Nuclear Energy

Since nuclear fission produces about ten million times as much energy per lb. as the best chemical rocket propellents, there are obvious attractions in the use of nuclear fuel. Rocket propulsion, however, requires not only a source of energy but a means of utilizing the energy to overcome gravitational and air forces and accelerate the vehicle to a high speed. This requires a continuous supply of propellent to be ejected from the vehicle to produce thrust.

Nuclear fission has been used to produce energy in the form of nuclear explosions and in the form of controlled heat as in applications to the generation of power in ships and on land. In 1947, Ulam of the Los Alamos Laboratory put forward the idea of propelling a large space vehicle by using the thrust of a series of small nuclear explosions in rapid sequence; this technique is undergoing further study at Los Alamos under support of the Atomic Energy Commission and at General Atomics under a contract from the Advanced Research Projects Agency of the Department of Defence.

The more conventional application of nuclear fission is to the nuclear rocket in which a reactor is used to add heat to a propellent which expands through a rocket nozzle to produce the propulsive jet. Project Rover, a co-operative programme between the A.E.C. and N.A.S.A., is intended to explore and demonstrate the feasibility of developing such a system.

In addition to applications of nuclear energy to the main propulsion system, there is much interest in nuclear energy as the source of auxiliary power in satellites and space probes. Communications equipment, auxiliary systems for attitude control, modification of orbits, and sensing devices for physical measurements, present continuing needs for power for as long a life as practicable. Many of the systems use electrical power and hence energy conversion devices are essential parts of an auxiliary power system for satellites.

There is much speculation about the development of nuclear fusion as a source of energy for space applications but until this method has been demonstrated for ground application, no serious work can be undertaken on space applications. It may be worth pointing out that for small power levels, solar power, which arises from nuclear fusion within the Sun, is and will find useful application in satellites and space probes.

Nuclear Rockets

The potential performance of nuclear rockets has been reviewed in numerous recent publications, for example, "Potentialities and Problems of Nuclear Rocket Propulsion," by T. P. Cotter of the Los Alamos Laboratory in the February, 1959, issue of *Aero-Space Engineering*, and four papers in the October, 1959, issue of *Astronautics* by Frank E. Rom of N.A.S.A., Jerry Grey of Princeton, Franklin P. Durham of Los Alamos, and Robert W. Bussard of Los Alamos.

The specific impulse of any rocket, including the nuclear rocket, is approximately proportional to the square root of the ratio of the absolute temperature of the propellent before expansion to the bulk molecular weight of the propellent. Thus the propellent should have the lowest possible molecular weight, leading to hydrogen as the most desirable propellent. The temperature should be as high as possible and is usually determined by the materials used. This requirement leads to the necessity for engineering compromises.

Rom points out that potentially uranium fission can produce specific impulses of the order of hundreds of thousands (compared to about 400 for the best high energy chemical fuels) but at operating temperatures of hundreds of billions of degrees Fahrenheit. Obviously a compromise must be made.

In a solid-fuel-element reactor such as the Kiwi-A reactor recently tested in Project Rover, the temperature of the propellent is limited by the melting points of the solid materials containing the fissioning material. The most refractory materials, not yet usable in practice, are the carbides of hafnium and tantalum which melt at about 7000° F. Most engineers agree that 6000° F. is about the maximum gas temperature which may be ultimately attainable in solid-fuel-element reactors after much research and development. The corresponding specific impulse would be about 1200–1500.

Rom then discusses the possible use of liquid-fuel-elements with hydrogen bubbling through, giving, if development proved possible, a specific impulse of 1500–1800. A further step is to consider a gaseous reactor with cooled walls, but this concept is still in the earliest exploratory phase.

The best appraisal of the present status of the development of nuclear rockets probably comes from the engineers and scientists of Project Rover. Durham gives a specific impulse of 800 as the early design objective and outlines the design considerations of a turbulent-flow solid-core heat-exchanger reactor. Bussard concluded that the specific impulse should be in the range 2000 to 5000 for hydrogen for a useful payload capacity on most missions of interest within the solar system, and that the specific power output should be aimed for 0·5 to 1·5 MW./lb., which would require gaseous reactors at temperatures between 20,000° and 60,000° R.

There is a fairly universal feeling that nuclear rockets are a necessity for the more difficult missions in which substantial payloads are given very large velocity

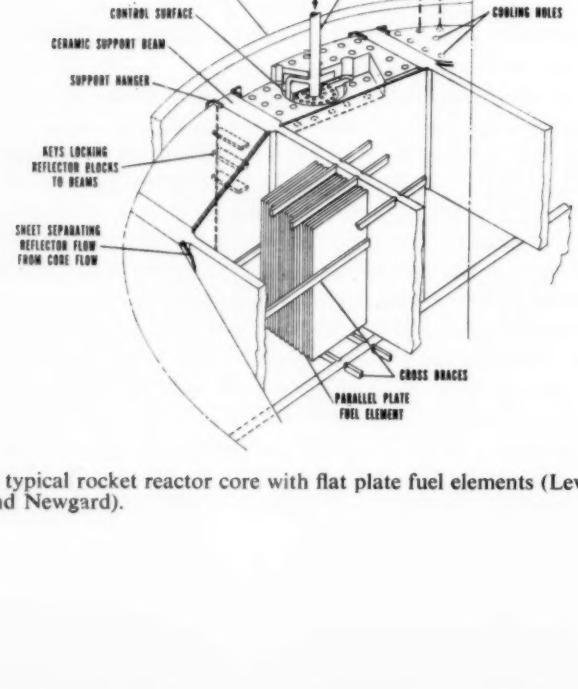
increments. As previously pointed out, the gain in specific impulse is in part offset by the greater weight of the nuclear rocket and this effect may be predominant if shielding is required.

According to Cotter the experiments now in progress represent a first but important step towards the development of a system which will not at first be greatly superior to chemical systems but which has great potentiality for development well beyond that possible for chemical systems.

Auxiliary Power

Nuclear energy is attractive as a source of energy for auxiliary power for use in satellites and space probes. The heat source may be a reactor or the energy of decay of radioisotopes may be used. In each case it is necessary to provide a conversion system to generate electrical energy from the heat energy, since most of the equipment in a space vehicle requires the energy in that form. The Atomic Energy Commission's Project SNAP is aimed at the development of systems for nuclear auxiliary power. N.A.S.A. intends to support the development of energy-conversion devices and to co-sponsor the development of systems required in the space programme.

Radioisotope sources are capable of supplying power over the range of 10 to a few hundred watts with presently available conversion devices at weights of 1·0 to 0·6 lb./W., according to a survey by Robert C. Hamilton of the Jet Propulsion Laboratory published in the August, 1959, issue of *Astronautics*. Devices dependent on radioisotope decay have a power output which decreases with time. The decay is at a slower rate for isotopes of long half-life. The power unit radiates, and the nature of the radiation from the specific isotope determines the amount of shielding and the precautions to be taken during launching. Only a few radioisotopes meet the requirements.



A typical rocket reactor core with flat plate fuel elements (Levoy and Newgard).

Thermoelectric converters of three types have been proposed for use with radioisotope sources. In the first, sometimes called the vacuum diode system, the heat energy is used to heat a hot plate which emits electrons to be collected on a cold plate, thus generating an electric current. The spacing must be very small in order to avoid limitations imposed by space charge. By the use of cesium vapour to form a conducting plasma the spacing may be increased to form what is often termed a plasma diode or plasma thermocouple. Finally, a thermoelectric semiconductor may be used. Heat is transferred by conduction to the hot junction of a thermocouple.

In January, 1959, the President described a demonstration unit, SNAP-3, developed under the sponsorship of the Atomic Energy Commisssion. Because it was readily available, polonium 210 was used as the source of heat, the hot junction of the thermocouple being heated to about 700° F. The cold junction temperature was about 180° F. The output was 3½ W. of 0·1 V. and the weight was about 5 lb.

All of these devices for direct conversion of thermal to electrical energy, although in their infancy, are also of interest for use with nuclear reactors as the heat source. Substantial increases in power density, operating temperature, and life are to be expected with further development.

For powers of 1 to 30 kW., Hamilton suggests that reactors using turbo-alternators for conversion may be obtained at weights of 500 to 200 lb/kW. for unshielded and 1000 to 350 lb./kW. for shielded systems. Light weight and long life while unattended are the conflicting requirements for acceptable systems. Such systems require the rejection of heat by radiation from a large radiator, the weight of which is a major factor in determining overall system mass. The radiator area and hence mass is affected by the choice of gas or metal vapour cycle.

Electric Propulsion

If a nuclear electric power system is required to meet the requirement of large amounts of auxiliary power, there are big advantages in using the same source for an electric propulsion system. Such systems using ion accelerators, plasma accelerators, arc jets, or one of the many other systems using charged particles or ions as working fluid, generate only a small thrust but the propellent consumption is very low so that operation may be continued over a long period of time. Electric propulsion is well suited for propulsion in interplanetary space and for control of the orientation and orbit of Earth satellites. Thus a nuclear electric turbo-alternator system may provide both propulsion and auxiliary power with resultant economy for some missions. Such a system must however function unattended for long

periods, one or more years, and under conditions of zero gravity. As in all space equipment there is a large premium on light weight.

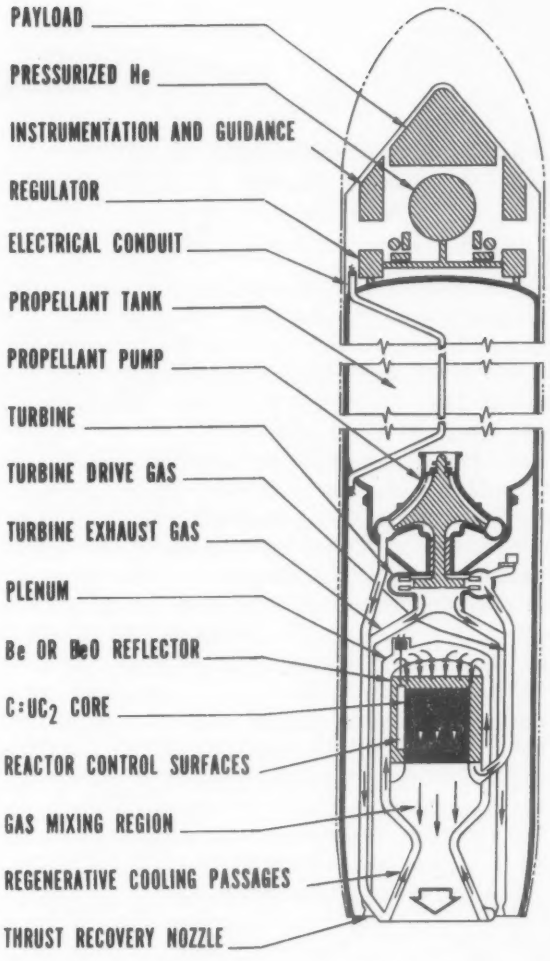
Special Research and Development Problems

The use of nuclear energy in space exploration requires an extensive supporting research and development effort on many special problems. For example, the greater weight of a nuclear rocket as compared with chemical rockets offsets to some extent the higher specific impulse, and efforts must be made to reduce the system weight. A key element is the reactor which must be as small as consistent with the required performance. Requirements for small size and high power lead to a high power density. High temperatures (4000° F. and preferably higher) and the desire for light weight results in high thermal stresses in the reactor fuel elements. The high temperature leads to the need for excess reactivity. The change in phase of the hydrogen propellent, involving a density change by a factor of 20, affects the dynamics of the system. Finally there are problems of corrosion, erosion, fuel bleedout, and power distribution. Some of these problems are discussed by Durham in the previously cited reference.

The problem of radiation damage in the nuclear rocket is unique by virtue of the high leakage fluxes and the wide temperature range that exists in the nuclear rocket. Payload, guidance, and control systems requiring transistorized circuits probably must be shielded. A really new area is the low temperature, high flux, exposure of the liquid hydrogen pump and liquid hydrogen tank. Because of the total lack of information, N.A.S.A. is negotiating a contract with the Marietta Division of Lockheed to conduct a research programme on the effects of radiation on the mechanical properties of materials operating at cryogenic temperatures. It is anticipated that the radiation effects may be severe under these conditions because there is no annealing at these temperatures.

Reference has been made to the need for large radiators in nuclear turboelectric systems. This gives rise to the need for much research and development in previously unexplored areas. Thus, if the working fluid is a vapour which condenses in the radiator, problems arise in the separation of liquid and vapour in a gravity-free field. The same problem is encountered in the venting of hydrogen in the propellent tanks when subject to radiant heating from the Sun. In order to radiate heat, the surface of the radiator must have a high emissivity. The emissivity may change with time during exposure to the space environment. The usual high-emissivity coatings may be unsuitable in the space environment. Meteoroids may erode the surface, changing its emissivity, or, if large enough, may puncture the radiator to cause leaks.

Finally, the presence of radioisotopes and nuclear reactors in satellites and space probes necessitates the study of operational requirements for their safe use.



Schematic diagram of a nuclear rocket employing liquid hydrogen as "working fluid" (Levoy and Newgard).

Conclusion

To summarize: (1) The potentialities of nuclear energy in the exploration of space are very great indeed both for primary propulsive power and auxiliary power. In fact, there are certain tasks involving large payloads accelerated to high velocities for deep space missions that cannot be accomplished by any other practicable means.

(2) Nuclear energy will probably first find space application in auxiliary power systems within the present decade. These same systems will find use in electrical propulsion at a later time, perhaps also within the present decade. A practicable nuclear rocket will probably be demonstrated toward the end of this period, possibly as an upper stage of an interplanetary probe, the reactor being started after escape velocity has been reached.

(3) The great advance in nuclear technology required for space application is bound to bring benefits to all nuclear technology, especially when, and if, the reliability needed for distant space missions of long duration is realized in practice.

Sputnik IV

Sent into orbit by a multi-stage rocket of the type test-fired into the Central Pacific last January, the fourth Soviet satellite—an embryo spaceship of 10,000 *lb., containing a "dummy" astronaut—was launched on* 15 *May. The following account of the events between* 19 *May and* 15 *June has been supplied by "Soviet News."*

On 19 May, 1960, the spaceship-sputnik completed its programme of observations. In accordance with the programme, at 2.52 a.m. on that day, a command was sent to the spaceship in order to switch on its braking device so as to deflect the ship down from its orbit and detach the pressurized cabin.

The device went into operation and the ship, as planned, was stabilized during the firing of the retro-rocket. However, as a result of a fault which had developed by that time in one of the instruments of the spaceship's orientation system, the direction of the retro-rocket's blast deviated from what had been planned and, as a result, the speed of the spaceship, instead of being reduced, increased slightly and the ship slipped into a new elliptical orbit lying in almost the same plane but having a much higher apogee.

The detaching of the pressurized cabin from the spaceship satellite was effected and normal working of the cabin's stabilization system was recorded.

As a result of the first launching of a spaceship-satellite a number of very important scientific and technical problems have been solved.

The reliable launching and flight of the powerful carrier rocket according to a pre-set programme, ensuring the placing of a spaceship in a nearly circular orbit, have been verified.

In the course of the flight reliable guidance of the spaceship-sputnik and its orientation was effected for several days.

Information obtained from the telemetered measurements shows that the system of conditioning and the heat control system of the spaceship have functioned normally throughout the entire flight and ensured the conditions necessary for future manned flights.

Telegraphic communication with the spaceship was normal. The telephoned rebroadcasting of transmissions from ground stations through the spaceship's equipment entailed noise with marked distortion.

The special radio-engineering facilities, designed for transmitting commands to the ship, controlling its orbital movement and transmitting telemetered information from it concerning the operation of the various systems on board, have effectively fulfilled their task.

The self-orientating solar batteries have functioned normally.

All the basic equipment for control of descent has been properly designed and can ensure the fulfilment of this task.

The results obtained from the first flight of a spaceship-satellite have furnished much data for achieving controlled human travel in space and have shown the correctness of the basic ideas underlying the spaceship's design. The findings from this effort make it possible for the experiments to be taken a stage further.

The spaceship-satellite and the pressurized cabin in its vicinity are now moving in an orbit with its lowest point at 307 km. (nearly 191 miles) and its highest point at 690 km. (over 428 miles), with a period of revolution of 94¼ min. The orbit's angle of inclination to the plane of the equator is 65 degrees.

The final stage of the carrier rocket continues in its earlier orbit. The spaceship's "Signal" radio transmitter continues to function normally, relaying back to the Earth information on the working of the systems and instruments.

Shrinking Orbit

The Soviet spaceship-satellite, launched on 15 May, completed its 486th circuit round the Earth at 6 p.m. (Moscow time) on 15 June. It had covered a total of 20,900,000 km. (nearly 13 million miles). The last stage of the carrier rocket completed 501 circuits during the period, travelling 21,100,000 km. (over 13,100,000 miles).

Since the spaceship went into its new orbit, its period of revolution has decreased by 5·4 sec. and now amounts to 94·16 min. Its apogee and perigee which were 428·5 and 190·3 miles respectively on 19 May, had dropped to 419 and 189 miles approx. by 15 June.

The jettisoned pressurized cabin continues to move along an orbit close to that of the spaceship, about 16 minutes behind it.

When the last stage of the carrier rocket was put into orbit, its period of revolution was 91·2 min., and its apogee and perigee were 229 and 195·5 miles respectively. In the past month, its period of revolution has decreased to 90·65 min., and its apogee and perigee to 195·5 and 192 miles respectively.

Visual and radio observations of the spaceship continue successfully. The beats of its "Signal" transmitter are being picked up by radio stations and amateur radio operators all over the world. The transmitter is supplying the Soviet tracking stations with continuous information about the pressure and temperature in the spaceship.

The processing of telemetered information shows that both temperature and pressure in the ship remain within normal limits.

New Soviet Space-Booster

We reproduce below extracts from "Tass" statements relating to the test of new multi-stage rockets by the U.S.S.R. on 5 and 7 July respectively.

In accordance with the space exploration programme, the Soviet Union launched a powerful carrier rocket without the final stage into the Central Pacific last January. On 15 May, this year, a spaceship-satellite of the Earth weighing 4 tons 540 kg. was launched in the Soviet Union by means of this rocket.

In accordance with the programme for further scientific research and experimental designing in the sphere of space problems, Soviet scientists and designers have prepared for testing new types of multi-staged carrier rockets.

Dummy Final Stage

In accordance with this plan, one of these rockets was launched on 5 July, The rocket was launched strictly on time. Its flight proceeded exactly in accordance with the pre-set programme.

The dummy of the last stage of the rocket, adapted for passage through the dense layers of the atmosphere, reached the surface of the water in close proximity to the target, about 13,000 km. (some 8000 miles) away from the launching site. Special vessels in the Central Pacific equipped with various measuring instruments took measurements envisaged by the programme and obtained valuable results.

In order to accumulate further experimental data the testing of powerful ballistic rockets will be continued. The rockets will fall within the boundaries of the zone indicated in the *Tass* announcement of 29 June of this year.

Programme Completed

A second successful launching of a powerful new multi-stage ballistic rocket designed for spaceflight was carried out on 7 July. The launching took place exactly on time and the rocket strictly followed the pre-set course.

According to measurements made by special vessels of the Soviet fleet, equipped with monitoring devices, the last, dummy stage of the rocket hit the surface of the water right on the target point. The firing range was about 13,000 km. (over 8000 miles).

The successful launchings of the new version of a powerful multi-stage carrier rocket on 5 and 7 July have fully completed the test programme of this version of the rocket.

These launchings yielded all the necessary data to complete the development of a carrier rocket designed for the further conquest of outer space.

In view of the good results of both launchings, no more testing of this version of the rocket is necessary.

Tass has been authorized to state that the area delimited by the co-ordinates specified in the *Tass* announcement of 29 June, will be open to shipping and aircraft from 8 July, ahead of the time originally stated.

First to recognise the opening of a new realm of flight by introducing a regular space-flight section, FLIGHT maintains the most comprehensive weekly coverage—latest news, illustrated features, meticulous cutaway drawings. For the first authoritative reports on space developments, read FLIGHT.

FLIGHT

Fridays 1s 6d

AIRCRAFT · SPACECRAFT · MISSILES

The Saturn Project

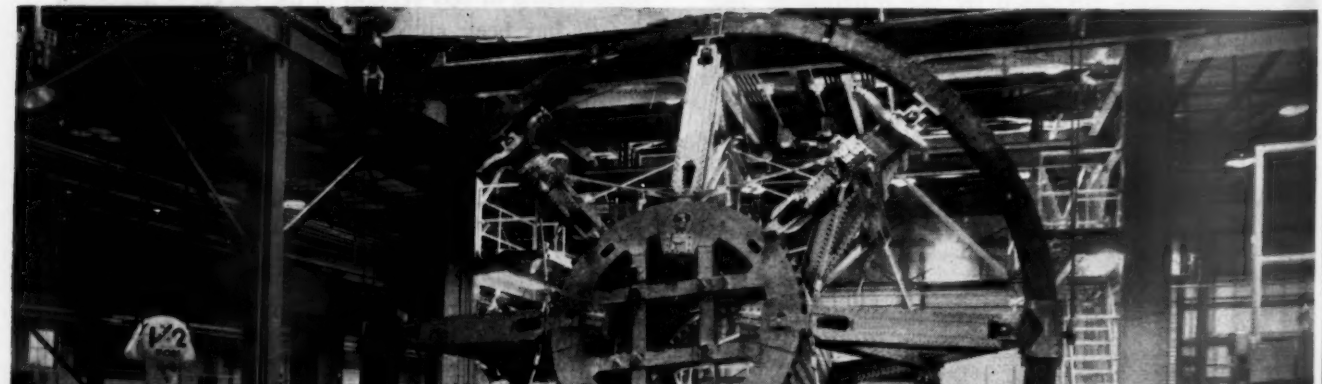
On 1 July, the Army Ballistic Missile Agency at Huntsville, Alabama, was formally handed over to the National Aeronautics and Space Administration to become the Marshall Space Flight Center. It is there that the eight-engine Saturn booster is being developed under the technical direction of Dr. Wernher von Braun. An early multi-stage version of this giant space-vehicle, Saturn C-1, will be capable of orbiting 25,000 lb. at 300 miles, or of launching 9000 lb. into deep space. With more energetic top stages, it should eventually be possible to double this payload capability. Static testing of a prototype, non-flyable, booster began in March this year; all eight engines were fired for the first time on 29 April. The prototype flight booster is already nearing completion at Huntsville and a test-firing from Cape Canaveral employing, in the first instance, dummy upper stages, should take place next year.

Static test prototype of the Saturn booster is moved from the assembly shop to the test-site.

Army Ballistic Missile Agency

Engine-mounting for the eight-engine booster before being removed from the assembly jig.

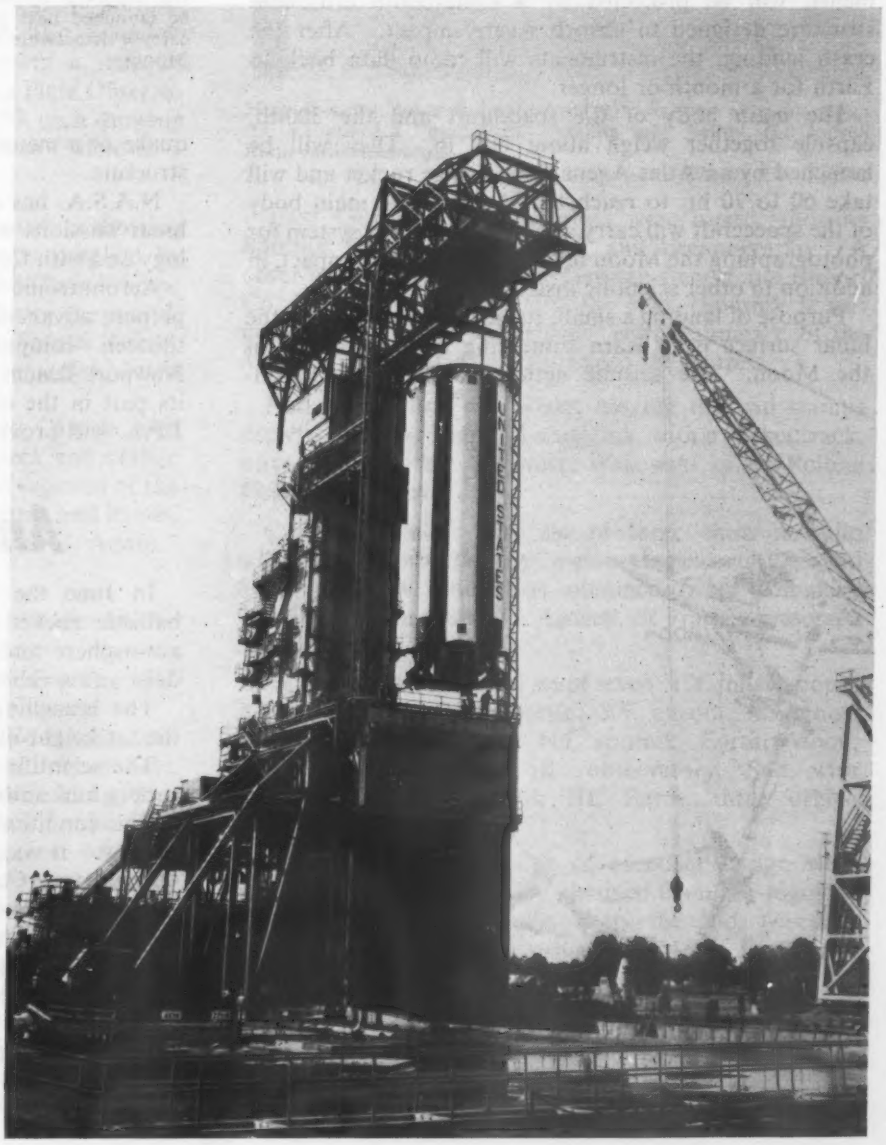
Army Ballistic Missile Agency



Above:

Measurements obtained from Saturn's static-firing are recorded in this instrumentation room of the Marshall Space Flight Center's test laboratories. The master control panel, in the centre of the room, controls the many tape and strip chart recorders mounted on the walls.

Army Ballistic Missile Agency



Right:

Giant cranes are used to lift the Saturn booster into position in the 177 ft.-high test-tower. The booster's 1,500,000 lb. s.t. is resisted by massive concrete foundations resting on heavy piling driven deep into the bedrock. Vertical loads are carried from the anchored booster through a retaining and measuring system to girders mounted on a load platform which, in turn, are connected to four corner columns secured to the foundation.

Army Ballistic Missile Agency

Moon-Landing Probe

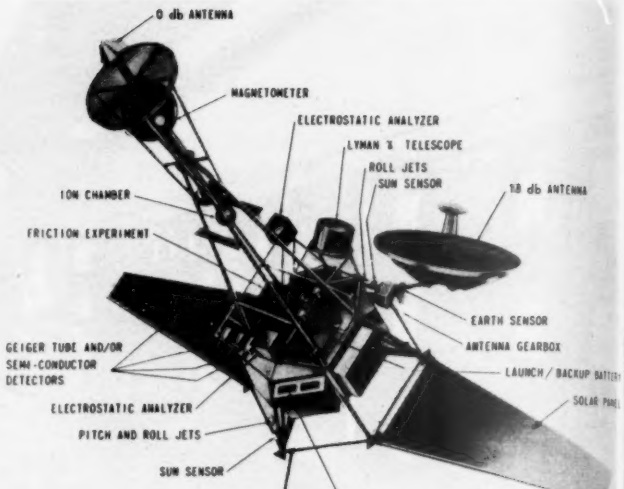
Our cover picture shows the configuration of the 300-lb. instrument package which the National Aeronautics and Space Administration hopes will be landed on the Moon in 1961–62. Under development by the Aeronutronic Division of the Ford Motor Company, it is designed to ride "pick-a-back" on a larger Ranger spacecraft now being constructed at N.A.S.A.'s Jet Propulsion Laboratory in Pasadena, California.

Briefly, its mode of operation will be as follows: At a distance about 20 to 25 miles from the surface of the Moon, the mushroom-shaped landing probe will be detached and a retro-rocket will reduce its speed at impact to less than 300 m.p.h. The parent craft will be destroyed as it hits the moon at a speed of more than 5000 m.p.h.

The 300-lb. instrument package, containing a seismometer, temperature-recording devices and other instruments, will be protected by a honeycomb crushable structure designed to absorb severe impact. After the crash landing, the instruments will radio data back to Earth for a month or longer.

The main body of the spacecraft and the 300-lb. capsule together weigh about 800 lb. They will be launched by an Atlas-Agena B two-stage rocket and will take 60 to 70 hr. to reach the Moon. The main body of the spacecraft will carry a television camera system for photographing the Moon up to the moment of impact, in addition to other scientific instrumentation.

Purpose of landing a small, rugged, seismometer on the lunar surface is to learn something of the makeup of the Moon. The seismic action caused by a Moon-quake or a meteor impact would offer clues to the lunar structure.

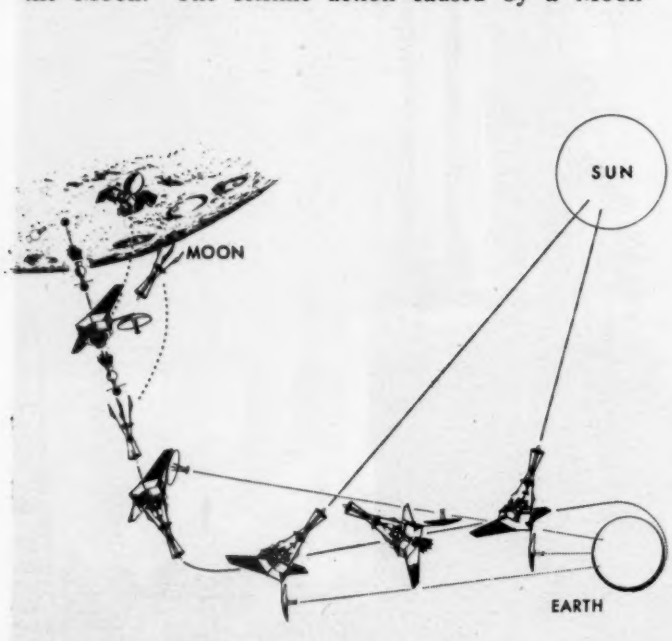


Instrumented test-version of the Ranger spacecraft which may be launched next year as a space-probe. A later version will carry a detachable 300 lb. instrument capsule for landing on the Moon.

Jet Propulsion Laboratory

N.A.S.A. has seismometer development contracts for lunar missions with the California Institute of Technology and with Columbia University.

Aeronutronic was one of three companies asked to prepare advanced capsule design studies after a total of thirteen companies had submitted proposals. The Newport Beach, California, Division of Ford estimates its part in the experiment will cost about $3·5 million. J.P.L. will provide technical direction.



Mid-course and terminal manoeuvres of the Ranger spacecraft en route to the Moon.

Jet Propulsion Laboratory

Animal Rocket

In June the Soviet Union launched a single-stage ballistic rocket for studying the upper layers of the atmosphere and outer space. The rocket carried two dogs and a rabbit.

The launching was successful. The missile reached the set height of 208 km. (about 130 miles).

The scientific apparatus carried, together with power supply and animals, weighed 2,100 kg. (2 tons 240 lb.).

The condition of the animals after landing is satisfactory. It was the fifth space trip for one of the dogs, Otvazhnaya (Courageous).

The research programme has been completed. Information has been obtained on ionizing clouds, which form at high altitudes, the ion composition of the atmosphere and its electrical properties, and the radiation of the Earth and Sun. In addition, new material was obtained on "the muscular tone of animals" under conditions of weightlessness.

Philatelic Safari

In search of stamps of the I.G.Y.

By DONALD MALCOLM, F.R.A.S.

Twenty countries commemorated the International Geophysical Year by issuing a total of sixty-two stamps, in twenty-one sets, and one minature sheet. I have included in my collection only those stamps bearing the inscription "I.G.Y."

As my primary interest in philately is cover collecting, I set out on an armchair safari, armed with persistence and International Reply Coupons, to obtain all the sets on covers. A cover is a complete envelope, with stamp, postmark and address.

Some of the stamps had been issued as far back as 1 July, 1957, the start of the I.G.Y., and this added to the excitement of the quest.

The South American leg of my search brought covers from Argentina, Chile, Colombia and Ecuador. ARGENTINA issued a 40c. stamp, showing a map of Antarctica. Sender: Dr. J. Sahade, of La Plata Observatory. The two CHILE stamps, $40 and $50, each showing her piece of Antarctica, were sent by Jose Galetovic—Castilla, Santiago.

COLOMBIA: A F.D.C. bearing the three values showing de Caldas, discoverer of hypsometry, was supplied by Senor Alfonso Salazar, Administration del Correo Aereo de Colombia. The ECUADOR stamp shows the world, with Sputnik and rocket orbits, and Saturn below. Sender: Lt.-Col. V. A. Rivadeneira, Director del Museo Postal.

Moving to North America, U.S.A. and Canada each issued one stamp. AMERICA: The 3c. black and orange stamp is beautifully designed. It shows a segment of the Sun, with prominences, and above, two arms and hands, a detail from Michaelangelo's "Creation of Adam." Sent by Max B. Miller, Los Angeles.

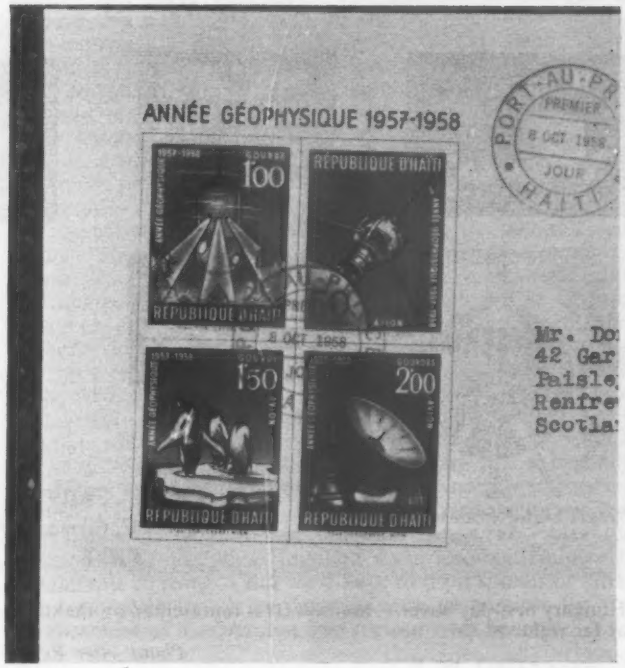
CANADA issued the Commonwealth's sole I.G.Y. stamp, a 5c. blue, depicting a microscope.

Two covers were sent by Mr. I. A. Dewar, who obtained them from the family Jensen in Canada.

Next stop, the Caribbean, to HAITI whose stamps, like her scenery, are in glorious technicolour. They are: 10c. and 50c. (air), Vanguard satellite; 20c. and 1g. 50c. (air), penguins on ice floe; 50c. and 2g. (air), radio telescope; 1g., oceanography. A miniature sheet with the four designs was also issued. The Haitian Ambassador in London, Mr. Colbert Bonhomme, obtained my two first day covers.

Still in the Caribbean, the NETHERLANDS ANTILLES stamp, showing a map of Curacao and positions of the Dutch and the American I.G.Y. stations, was sent by Mr. J. D. Vance of M.V. *Patella*.

The Iron Curtain countries issued a total of 33 stamps.



Haiti first-day cover (miniature sheet). Stamps at right depict the Vanguard I "grapefruit" satellite and, below, the Jodrell Bank radio-telescope.

Photo: Alec Rogers

EAST GERMANY: Three values were issued, showing Sputnik I, stratospheric work and oceanography. A cover was obtained from the German Export and Import Co. Leipzig. Unfortunately, the 10pf. (Sputnik I) was no longer valid for postal use. Herr Baumgart, of the Ministry of Postal Affairs, supplied the address.

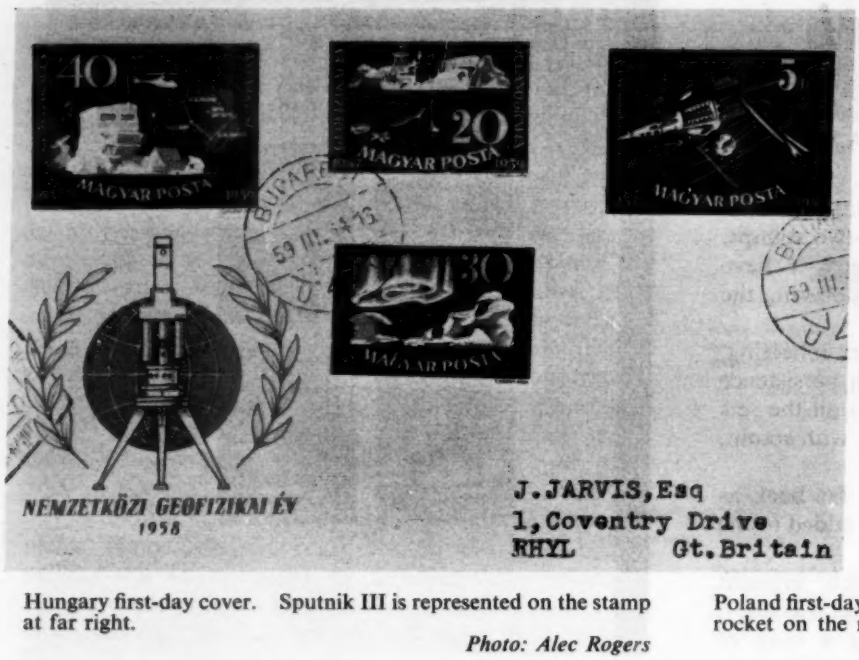
POLAND: A first day cover, bearing the two stamps depicting a polar bear and a sputnik, with a rocket track, was supplied by Mr. Kazimierz Wasowski, of Ars Polona Philatelic Agency.

CZECHOSLOVAKIA: The set of three show a radio telescope and observatory, meteorological station, and Sputnik II. A cover was obtained from Lomnicky Stit, while Artia Philatelic Agency, of Prague, presented two covers.

HUNGARY: A wonderful set of seven: 10f., microscope; 20f. sonar vessel in Antarctic; 30f. aurora; 40f. snow plough, Antarctica map; 60f. sputnik, Earth, Moon, Saturn, Jupiter, stars; 1ft. observatory, Sun with prominences; 5ft. Sputnik III, Earth, three orbits, Lunik.

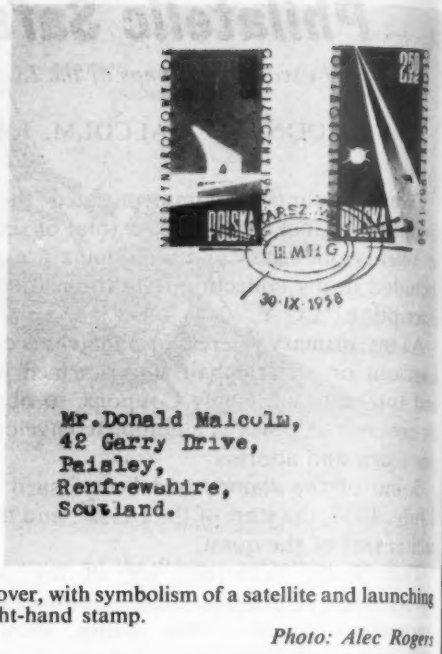
JUGOSLAVIA: Two stamps of excellent design were issued. The first day cover, obtained from the Jugoslav Philatelic Agency, Belgrade, bears the 15d. (oceanography) and the 300d. (air value; half-Moon, Earth with three orbits).

RUSSIA: The issue here was two sets of three stamps, all 40k. in value. They show an observatory interior, meteor track, and a rocket in the sky; the second set represents meteorology, geomagnetism, and auroral



Hungary first-day cover. Sputnik III is represented on the stamp at far right.

Photo: Alec Rogers



Poland first-day cover, with symbolism of a satellite and launching rocket on the right-hand stamp.

Photo: Alec Rogers

phenomena. Covers supplied by Eugene K. Strout, Moscow.

BULGARIA issued two stamps with the same design, Sputnik III in orbit over Earth, one perforated, the other imperforate. A well-postmarked cover came from G.P.O. Sofia.

The Far East is represented by JAPAN (one stamp), INDONESIA (five stamps) and NORTH KOREA (eight stamps, four perforated, four imperforate, same designs each set).

JAPAN issued a 10y. stamp on 1 July, 1957. It shows a sputnik orbit, a penguin and the vessel Soya. A cover bearing two copies, postmarked in English and in Japanese respectively, was kindly sent by an unknown official of the Tokyo Philatelic Agency, who took them from his own collection.

INDONESIA: The five stamps, delicately tinted, each show a satellite in orbit. (Sender: Office of Posts, Telegraphs and Telephones, Bandung).

NORTH KOREA: I have been unable to obtain the sets.

FRANCE is represented by three Antarctic stamps, each showing a polar base and a meteorologist. A cover, bearing the stamps, which have travelled about 50,000 miles, is at present on the high seas aboard S.S. *Norsel* (early March).

In conclusion, I'd like to thank the dozens of unknown people throughout the world who have shown that a spirit of helpfulness still exists, and who have been instrumental in making this philatelic safari so successful and full of interest.

All that remains now is to mount the "trophies."

Correspondence

SIR,—I do not think the Solar-Drive proposed by Mr. Camp[1] would provide a "super exhaust velocity power unit." In the first place, radiation can heat only opaque and not transparent materials: therefore if the liquid in Mr. Camp's vessel does not absorb the solar radiation before it reached the focus it will not do so at that position either. Further, since pressure acts equally in all directions, a pressure sufficient to expel the working fluid at a super velocity would surely disrupt the transparent window.

University of Cambridge. ROGER GRIFFIN.

1. J. R. Camp, *Spaceflight II*, 154, 1960.

"*Subscriber's Lament*"

SIR,—I would like to record my delighted appreciation of "J. G.s" versified heart-cry printed in the April issue of *Spaceflight*. "*Subscriber's Lament*" reflects and neatly expresses my own feelings—and probably those of many other B.I.S. members, who, like myself, do not possess six-dimensional mathematical brains and a tame computer.

Nevertheless, one must concede that the highly technical matters (some of them at any rate) dealt with in the Journal are necessary—indeed, surprisingly enough, occasionally even capable of practical interpretation and elaboration. But for me most of the articles are largely unintelligible, boring, and over the course of years repetitive to the point of nausea. So many people seem to be patiently engaged in inventing methods and things that were thought of long long ago by the great astronautical pioneers, such as Ziolkovsky, Oberth, Goddard, Esnault-Pelterie, and Pirquet. In fact, I am confidently expecting that in the near future someone will reinvent the solid-fuel B.I.S. spaceship! As for orbits, well everyone seems still bemused by the Hohmann "co-tangent" paths, regardless of the clearly apparent fact that they entail such precision of timing combined with excessively long "waiting-times" in the vicinity of the target planet, or on it, as to render them just plain suicidal for manned interplanetary ventures.

I for one, then, would like to see the Journal contain more articles which exhibit original thinking and new approaches to problems—and so far as possible a minimum of mathematical contortions.

Otherwise, there is, of course, one solution readily available—to adopt the proposal made by Arthur Clarke in a pre-war Bulletin, *viz.*, a separate supplement for equations and graphs, "so that they can be filed by the technical members and safely lost by the non-technical."

H. E. Ross.

Blue Streak and Space-Co-operation

Sir,—I should like to take issue with some of the points raised in the editorial on Blue Streak in the April issue.

It cannot be said that the problem of combining a developed Blue Streak with Black Knight and a solid propellent rocket for launching a satellite is a "relatively small" step. One must bear in mind that only one thing may go wrong in any one of the stages to make such an operation a failure. American experience with multi-stage vehicles shows how costly and heartbreaking such failures can be during a development programme.

The editorial expresses the fear that we are in danger of losing our technical competence in high performance rocketry. It is perhaps worth while reflecting on just how limited that competence is at present. In terms of proved hardware it is embodied in small missiles and booster rockets. Our longest range vehicle is Black Knight which is essentially an up-and-downer of relatively conservative design having a performance that may be compared with Russian and American vehicles of up to a decade ago. We all wish the Blue Streak people well, and the intentions of all who strive for its realization as an operational vehicle* are deserving of the greatest praise and encouragement. But we deceive ourselves when we confuse the intention of today with the realization of tomorrow.

The Editor says we must seek ways of advancing our own technology in the space sciences, and every member of the Society will agree with him. The question is *how* best to achieve this end? He wants to see the establishment of a Commonwealth Space Authority as a first step. With Canadian missilery closely allied to the American programme in an integrated programme for the North American Continent, and with only small or non-existent aircraft industries in other Commonwealth countries, it is difficult to see what such an Authority would be expected to achieve.

A more practical approach would be to explore further the possibilities of co-operation with the United States, extending the present effort on the scientific plane to the technological plane. They have the large rockets and a vast programme of future developments in hand. We have research facilities and manpower that could usefully be employed in an integrated programme under their general direction. Against this background a Western World Space Programme could emerge.

Such a suggestion raises objections from hardened nationalists, who are unable to view each new situation objectively as it arises. Curiously such die-hards would probably contemplate with approval the views of Varvarov in the same issue as the Editorial under discussion regarding the desirability of pooling scientific effort and material resources in sending manned expeditions to the planets. An explanation of this is probably to be found in the time factor. To face the desirability of accepting direction from another country is unpalatable to some. But we'll have to do it sooner or later, and I advocate that it be done as soon as possible for the advancement of astronautics and for our own benefit.

S. W. Greenwood.

2 Tower Walk,
Weston-super-Mare, Somerset.

* *This letter was received a few days before Blue Streak was cancelled as a military weapon.*—Ed.

New Evidence of Martian Life

By MICHAEL H. BRIGGS,* M.Sc., F.R.A.S., F.B.I.S.

Until recently there was very little satisfactory evidence to support the widely-held belief that living things occur on the surface of Mars. The atmosphere of the planet is largely nitrogen with traces of carbon dioxide and the inert gases.[1] There is no free oxygen and consequently no chance of animal life as we know it. It necessarily follows that the only organisms that could survive the Martian conditions are some types of plant life.

Much optimism has centred around the fact that many observers of Mars have reported the presence of green patches on the surface. Unfortunately the colour cannot be detected spectroscopically and it is quite likely that the observed green shades are only a complementary hue produced psychologically by the red-yellow of the deserts. The colour changes with season reviewed by E. M. Antoniadi[2] may similarly be mainly illusory, though it is likely that some regular alteration does occur on the Martian surface. For this reason the title of the well-known book on Mars by H. Strughold[3] is highly misleading.

The absence of atmospheric oxygen is a problem that must be solved if vegetation occurs on Mars. The photosynthetic by-product may never be released by the plants[3] or the temperature of the upper layers of the Martian atmosphere may be sufficient to facilitate the gravitational loss of the gas.[4] Alternatively the organisms could contain an efficient oxygen acceptor system.[5] All these possibilities could account for the absence of oxygen and still allow the existence of surface plant life.

The recent attempt by Webb[6] to revive the canal theory of Percival Lowell has not met with much favour. There is still no convincing evidence that the Martian surface possesses the numerous straight fine lines required by the theory. The best photographs have revealed only broad diffuse markings. Consequently the thorough work of Webb in analysing maps of the canals is, on the whole, rather pointless if they are illusions. A similar analysis could be made of the canals of Venus of which Lowell was a foremost proponent.[7] It is known that the latter are certainly not real.

The only other source of evidence for Martian life came from attempts to detect chlorophyll. This substance has the property of reflecting strongly in the infra-red region of the spectrum. Hence if chlorophyll occurs on Mars, light from the planet should show this high reflectivity. Numerous tests, however, have failed to detect radiation of this type.[8,9,10,11] This leaves only two alternatives. Chlorophyll does not occur on Mars.

* *Department of Chemistry, Victoria University of Wellington, New Zealand.*

Or there is some effect which alters the characteristic reflection of the compound. Unwilling to accept the absence of chlorophyll, most people have chosen the second alternative and have proposed details of plant structure that could account for the lack of near infra-red in the Martian spectrum. G. de Vaucouleurs[12] has suggested that infra-red reflection is a property of the air-spaces of a plant and that under the lesser atmospheric pressure of Mars the reflection would be correspondingly reduced. A. E. Slater[13] proposes that Martian plants protect themselves from the cold by means of some substance which absorbs infra-red radiation, analogous to the resinous materials in the leaves of fir trees. This is supported by the observations of Tikhov.[14] Finally, G. P. Kiuper[11] has found that the infra-red reflection from lichens is much less than from higher plants. Consequently the observed properties of the dark regions of Mars are compatible with the existence of low forms of plants of this type.

It will be seen, however, that this evidence is far from conclusive in demonstrating the existence of Martian life. It is not surprizing that alternative explanations of the dark areas have been proposed. For example the volcanic ash hypothesis of McLaughlin[15,16] has attracted a good deal of attention, but it is hard to reconcile with the rapid regenerative properties of the dark areas.[17]

Infra-red Spectroscopy

It is well-known that all organic molecules possess strong absorption bands at 3·5 μ as a result of resonance of their carbon-hydrogen bonds. Now although the presence of organic molecules does not necessarily prove the existence of living things (for example simply hydrocarbons occur on Jupiter which is almost certainly lifeless), the absence of organic molecules proves the absence of life. If life exists on Mars it should be possible to detect the 3·5 μ infra-red absorption in the Martian spectrum. The first attempt to detect this band was made by William M. Sinton of the Lowell Observatory, Flagstaff, Arisona, in 1956. He used the 61-in. telescope of the Harvard College Observatory. In his report[18] he claims to have detected the absorption band, but was uncertain of its origin. Obviously more detailed experiments were required. These have now been carried out and the results published.[19,20]

At the opposition of Mars in 1958 Sinton was allowed the use of the 200-in. Hale telescope at Mount Palomar Observatory. In the place of the previous spectroscope he used a special instrument: a liquid nitrogen-cooled lead sulphide detector. Spectra were obtained of various regions of Mars, together with five of the most prominent surface marking, the Syrtis Major. For comparative purposes spectra of the Sun also were obtained.

On careful examination of the Martian spectra absorptions were detected at 3·43, 3·56, and 3·67 μ. The middle absorption band coincides almost exactly with the 3·5 μ absorption of organic compounds. But of even more interest was the fact that the band was present only in the dark areas of the Martian surface, not in the deserts. The relative intensity in four dark areas was approximately 2, while the intensity in spectra of the desert regions was only 0·3 to 0·5. Consequently whatever material is the cause of the absorptions (presumably organic compounds) is confined to the dark areas.

Sinton was puzzled by the absorption at 3·67 μ. He examined a number of plants spectroscopically in the hope of finding one that would give this absorption. The band was absent from most plant spectra, but finally it was found in the spectra of both *Physcia* and *Cladophora*. The first of these plants is a lichen, the second an alga. The cause of the band is still not finally settled, but it appears to be produced by carbohydrate molecules. Two of the most prominent plant substances, cellulose and starch, are carbohydrates.

Sinton took the opportunity to examine his infra-red spectra of Mars for the presence of methane and carbon dioxide. The absorptions due to methane were no stronger in the spectra of Mars than in that of the Sun, proving the almost complete absence of the gas from the planet's atmosphere. Carbon dioxide, however, was present in appreciable amounts. This result confirms the earlier finding of Kuiper.[21] No appreciable quantity of nitrous oxide (a product of bacterial metabolism) was detectable on Mars.

This work by Sinton must be considered an outstanding piece of research. Although it does not conclusively demonstrate the existence of life on the surface of Mars, it makes it very likely.

Future Research

The application of infra-red spectroscopy to the study of the planets opens up new horizons. It is probable that the new techniques can be applied to both Venus and Jupiter; two planets that may also possess simple organic molecules. It is known that Venus possesses dense white clouds. The composition of these clouds is not known, but two recent suggestions[22,23] both postulate organic molecules. Similarly it is known[24] that the atmosphere of Jupiter contains methane and higher paraffins may also be present; perhaps with unsaturated hydrocarbons.[25] Whether the presence of these compounds is compatible with the recent detection of nitrogen tetroxide in the atmospheres of both Venus and Jupiter[26,27] must be decided by future research.

Conclusions

Studies of the infra-red spectra of Mars have shown the presence of absorption bands probably due to organic compounds. Moreover these absorptions are characteristic of the spectra from the dark areas of the surface. This evidence points to the existence of complex organic substances in these areas of Mars. The absorptions typical of carbohydrate molecules were found in the spectrum of a lichen. As was discussed above, the presence of plants of this type would provide an explanation of the negative results for chlorophyll.

[Continued on page 259

Shaping the Space-Programme

We publish below a summary of the recommendations submitted by the British Interplanetary Society to the Prime Minister and the Minister for Science on the subject of U.K. participation in aerospace development.

1. THE URGENT CHALLENGE OF ASTRONAUTICS

1.1. A British entry into space activities on a more comprehensive scale than has hitherto been officially proposed, has now become essential if we are to maintain our position in world technology.

There has in the past been an apparent official tendency in the U.K. to consider astronautics purely in terms of the scientific observations and experiments which can be performed with high altitude rockets and close orbit satellites. This is unduly restrictive in outlook: such aspects cover only a small though important part of the whole field.

To emphasize the above point, British aviation policy in (say) 1910 could not have been determined merely by considering the influence of the new art on our knowledge of meteorology and surveying. As history has shown, the significance of aviation was quite different and much more far reaching. In much the same way, astronautics has a much broader significance than merely providing a new outlet for research in certain areas of physics.

1.2. Mankind is on the verge of entering a long new phase of exploration and development, comparable to the conquests of the oceans and the air, but vastly exceeding these in scope. In this context, the views of historians and sociologists on the lessons from past explorations and expansions are as worthy of a hearing as those of contemporary specialists in science and technology.

What will almost certainly turn out to be a complete revolution in human affairs and progress cannot be ignored by this country, which has a long history of being in the forefront of exploration.

1.3. Apart from the ultimate implications that space exploration will have for the future of mankind, astronautics is the greatest challenge to applied science and technology today. Any nation that contributes to it in an important way will derive considerable benefit, both directly, in terms of general advances in technology, and also in the indirect non-technical sense.

1.4. Of the relevant non-technical considerations, one often mentioned is that of national prestige.

The less-developed countries of the world will tend in future to judge the leading nations at least partly on the basis of their achievements in space. Such judgements will inevitably be reflected in their purchase of technical equipment of all kinds. Should the belief develop that Great Britain is lagging in this most important branch of technology, our international status is likely to be undermined, for example, at international conferences when relevant problems are discussed.

By entering on a significant space programme, Britain will strengthen her position as a leading nation of the Western World and as a leading member of its various political, trade and military alliances.

No one could deny that Russia's success in space has established her as one of the two most advanced countries in science and engineering. Already this has had a marked effect on her position in international trade and politics.

1.5. Allied to the question of prestige overseas is that of internal morale. This is inseparable from the general sense of national achievement, the stimulus to technology and the encouragement of new industries with new products.

In this respect, astronautics will play a future role equal to, and possibly greater than, that of aviation during the past 50 years. If Britain does not enter this new field, there is a grave danger of contributing still further to the growing tendency for British research and development in the fields of applied science and technology to be associated almost entirely with objectives of immediate military, commercial and economic importance. If this tendency continues, then the achievements of our scientists and engineers will become as limited as their objectives, and there will be an inevitable decline in both the level of British applied science and technology, and in the morale of the people involved.

2. BENEFITS FROM A SPACE PROGRAMME

Apart from the above general considerations, there are important and specific military and civil developments which can be foreseen for the future. It is possible to list a number of potential benefits which might accrue to a nation participating in such developments, although the important possibility of quite unpredictable gains must always be a vital factor in exploration.

The forseeable practical benefits from a space programme fall logically into three distinct categories, namely the results of pure space research, the practical uses of space vehicles and the by-products of space technology.

2.1. The Results of Pure Space Research

By this is meant the researches into pure science (*e.g.*, physics) rendered possible by the use of space vehicles. Obviously, the ability of British scientists to conduct such researches would be greatly enhanced by the availability of British vehicles, with the consequently greater measure of control over the launching programme, etc.

2.1.1. In general, scientists do not undertake such pure research primarily with a view to the ultimate application of the new knowledge so obtained, but rather because it is valued for its own sake. (An example of such a discovery from space research is the van Allen radiation belts.) However, practical applications invariably follow, though they are essentially unpredictable in any detail.

2.1.2. Examples of such possible applications, in this context, are—

(*a*) Better weather forecasting, eventually perhaps even some measure of weather control, resulting from improved knowledge of the mechanism of weather formation. This is distinct from the *direct* benefits from meteorological observation satellites, mentioned in 2.2.2.

(*b*) Similarly, improved radio communications, resulting from greater knowledge of the ionosphere. Again, this is distinct from the *direct* benefits from communications satellites, mentioned in 2.2.1.

(*c*) The nuclear reactions used in bombs and power plants were largely studied, in the first place, because of their relevance to astrophysics. Space research promises to increase our knowledge of this subject. Thus there may be a significant feedback into the applied field of nuclear technology.

(*d*) In space, opportunities will arise to study physical phenomena in a completely new environment, not reproducible on Earth, *e.g.*, in the gravity-free or "weightless" state, in extremely high-vacuum conditions on a large scale, and at very high relative velocities. Past experience suggests the strong possibility of new discoveries and applications.

2.2. Practical Uses of Space Vehicles

It is just as difficult to discuss these in terms of firm dates, numbers, or costs as it would have been for air pioneers in 1910 to predict the volume of trans-Atlantic air traffic in the 1960s, its fares or journey times relative to sea travel, and so on.

However, the following possibilities all appear feasible, on a progressively extending time-scale:—

2.2.1. Communications satellites, first for speech, later for TV. Such satellites have potentially greater capacity and economy than current terrestrial radio or cable systems, which therefore may eventually be largely superseded. In fact, a country which does not have communications satellites of its own, may find itself out of the long distance communications market altogether.

The communication satellite represents an immediate commercial application of astronautics, and a fuller discussion of this subject is given in the Appendix.

2.2.2. Meteorological observation satellites, to give longer warnings of impending weather situations. This would have a considerable commercial value.

2.2.3. Military reconnaissance satellites, in due course of a recoverable type.

2.2.4. Long-range terrestrial transportation, using near-satellite vehicles. This should certainly have military applications (*e.g.*, the American "Dyna-Soar" project). It might eventually have commercial ones (Australia in about 2 hr.), if further improvements were needed on the speeds and ranges attainable by supersonic air-breathing aircraft.

2.2.5. Military satellite vehicles, and later even extra-terrestrial bases, for launching retaliatory nuclear attacks: the corresponding counter-measures would follow, on the "fighter *v.* bomber" analogy. Basically, the advantage here would be to remove any possible gain to a potential enemy from delivering a surprise attack: radar warnings could be increased from a few minutes to several hours or even days.

2.2.6. Interplanetary discoveries. Anything found on other worlds in a form unknown on Earth would acquire a commercial value (even if perhaps an artificially high value, like that of gold or many precious stones).

2.3. The By-products of space technology

These result from its stimulus to other fields. It is not suggested that the development of space vehicles is unique in this respect, as compared with other advanced technical projects. However:—

(*a*) It probably embraces a wider range of disciplines and therefore will have more side-effects.

(*b*) It probably presents the most difficult and challenging problems, and therefore will produce the greatest stimulus.

Examples of these by-products or side effects can be expected in all the following fields: indeed, many of them have already proved to be significant:—

2.3.1. *Cryogenic Engineering*

(Employment of liquefied gases at very low temperatures.)

In rocketry, liquid oxygen and hydrogen are produced and handled on a very large scale, with the attendant development of suitable materials and techniques for structures, seals, etc.

This work for specific objectives overshadows any which may be sponsored, on a purely abstract basis, by the NRDC.

Probable applications elsewhere concern electronic devices employing the principle of super-conductivity (*e.g.*, in switching and memory circuits for digital computors), for industrial and aircraft use as fuels, and as an energy storage medium for nuclear or hydroelectric power, etc.

2.3.2. *Electronics*

Instrumentation techniques developed for satellites and space probes are likely to find other uses. This also applies to the instruments designed to measure transient phenomena of rocket engines such as high flow rates of unusual liquids, high temperatures, etc.

The computers and guidance systems of rocket vehicles demand light and compact, rugged and miniaturized, circuitry of high reliability. Transistors and potted or printed circuits have been developed largely to meet these needs, and are finding widespread application elsewhere.

2.3.3. *High-duty mechanical devices*

The highly-loaded gears, novel lubrication systems, control valves and high-performance pumps of rocket engines are examples of general advances in detailed mechanical engineering, which are gradually absorbed into general industry.

2.3.4. *Materials*

The high working temperatures of rocket engines stimulate work in the fields of metallurgy and refractories. At the other end of the temperature scale, the use of cryogenic fluids (see 2.3.1.) develops low temperature materials. Both these temperature extremes, and also the widespread use of corrosive fluids, encourage the production of specialized plastic materials, which invariably find other uses in due course (for example, polythene).

The demand for low structure weights in the vehicles themselves similarly stimulates the development of advanced materials, and design techniques.

2.3.5. *Fabrication Techniques*

The welding and brazing of difficult alloys, and the fabrication of novel shapes by such techniques as flow-turning or explosive-forming, are all being encouraged by the needs of rocketry and spaceflight.

2.3.6. *Chemical Technology*

Such rocket propellents as high test hydrogen peroxide and hydrazine have already found other more general applications. Rocketry places a high premium on the development of highly-energetic solids and liquids, and so stimulates the chemical industry. Any super-fuels developed in the future would very probably have a widespread application.

2.3.7. *Power Generation*

In various ways, the requirements of spaceflight encourage progress in this field, with results likely to be extremely significant for many purposes.

Satellite power supplies demand lightweight batteries, solar cells, radio-active or thermo-electric devices, fuel cells, etc.

Many of the engineering problems involved in the direct conversion of heat energy into electricity (currently being studied by the CEGB and other organizations) are very similar to those involved in rocket engines. Novel rocket propulsion systems of the ion and plasma type would also contribute to the above; indeed, they would in themselves provide a major incentive for the production of a direct conversion system, of high cycle efficiency and with no rotating machinery.

Small commercial plasma jet units are already being marketed by the U.S.A., to aid the development of refractory materials, etc.; their own development was largely supported by research expenditures on ballistic missile re-entry and space propulsion.

Work on nuclear rocket engines would supplement and extend that on ground-based high temperature reactors, and on direct-conversion systems. In short, all this class of work affords outstanding opportunities for cross-fertilization.

3. THE AMERICAN SPACE PROGRAMME

As a yardstick in discussing a British space programme, it is useful to consider in broad terms the space activities of the United States. Full details of the U.S.S.R. programme are not available, but this is at least equally ambitious and probably further advanced.

3.1. Most of the American effort devoted to the development of spaceflight for other than military purposes is now controlled by the National Aeronautics and Space Administration (NASA). When NASA was set up in mid 1958, it took over all the staff and facilities of the NACA, namely 8000 scientists, engineers and supporting personnel, and laboratories and equipment worth $350 million. The budget for the fiscal year 1959 totalled over $300 million, in 1960 it is nearly $500 and in 1961 will be nearly $1000 million.

3.2. Considering the 1960 fiscal year in more detail, the total budget is made up broadly as follows:—

Research and development	$333 million
Salaries and expenses	$ 94 million
Construction and equipment	$ 58 million
TOTAL	$485 million

3.3. The NASA research and development programme is extremely comprehensive, and is by no means confined to launching satellites and space probes for research. The immediate goals of the programme are to learn more about the Earth, the atmosphere that makes life possible, the Moon, the closer planets and whether man can exist in space. The ultimate goals are to learn and understand about mankind and his environment, and their origins and destinies.

The 1960 budget can be broken down into the following headings:—

Aircraft, missile and spaceflight research	$30 million
Scientific investigations in space	$47 million
Satellite applications investigation	$15·5 million
Space Operations Technology	$73 million
Space Propulsion Technology	$52 million
Space Systems Technology	$ 5 million
Supporting activities (Tracking, etc.)	$11·5 million
Vehicle Development	$99 million
TOTAL	$333 million

3.4. Highest priority in the NASA programme is at present given to Project Mercury, in which it is intended to put a man into a close orbit about the Earth and recover him safely. In fact, during 1960, $70 million is budgeted for manned spaceflight investigations.

Engines and propulsion developments figure prominently in the programme, with $30 million being devoted during the year to work on the 1½ million pound thrust engine which is under development at Rocketdyne. It is estimated that the development of this engine will take 5 to 6 years and cost a total of $250 million. Considerable emphasis is also given to the development of high-energy propellent rockets, notably liquid hydrogen/liquid oxygen engines.

The NASA launching vehicle programme will develop in logical steps. The Atlas ICBM will form the first stage in Agena and Centaur, which are two- and three-stage launching vehicles respectively; they should be available in 1961. These vehicles are capable of launching more than 3000 lb. payloads into a close orbit around the Earth or of depositing 700 lb. in a soft lunar landing. Centaur differs from Agena in having two liquid hydrogen/liquid oxygen engines of 15,000 pound thrust in the second stage, instead of a conventional rocket.

More ambitious is the four-stage Saturn launching vehicle, weighing nearly 600 tons at take-off. Saturn C-1 will employ a cluster of eight Rocketdyne engines developing 1·5 million pounds combined thrust, with a cluster of four 20,000 lb. s.t. LO_2/LH_2 engines in the second stage. The third and fourth stages of Saturn will be identical with the second and third of Centaur. Saturn may be flight tested in 1961 and will be capable of placing a 30,000 lb. space laboratory, with a crew of five into an orbit round the Earth.

The most ambitious launching vehicle is the five-stage Nova. This lies several years in the future, since its first and second stages will depend upon the 1½ million pound thrust Rocketdyne engine, the first stage using four of these and the second stage using one. The third stage of Nova will use an 80,000 pound thrust liquid hydrogen/liquid oxygen engine, now under development, while the fourth and fifth stages should use the same engines as the second and third of Centaur. Nova would be capable of lifting about 150,000 lb. into a satellite orbit or of landing two or three men on the Moon.

It will be seen that the NASA vehicle programme is very economical in minimizing the number of different individual engines employed. However, over a period of about 10 years, approximately $2000 million will be spent on the development and operation of these launching vehicles. It has been stated that a single launching of a 1½ million pound thrust vehicle will cost $20 million. On that basis one might expect a single Nova launching to cost of the order of $100 million.

4. WHAT COULD BRITAIN DO?

It will be fully appreciated that the U.K. cannot possibly hope to compete on equal terms of expenditure and diversity of projects with the U.S.A. (or U.S.S.R.). To assume, however, that we can therefore play no significant part at all, would be a betrayal of our national future. The installation of British instruments in American satellites is a step in the right direction, but cannot be regarded as constituting a "significant part" in this sense.

4.1. The possibility of using Blue Streak and Black Knight as a two-stage satellite launching vehicle has been seriously proposed in many quarters. The payload capabilities of such a launching vehicle would be in excess of 1000 lb. for a close Earth satellite orbit.

This is an obvious and vital first step for a British space programme. At the time of the cancellation of Blue Streak as a weapon, about £65 million had been spent on its development, including the development of the Black Knight test vehicle and the engine test beds at Spadeadam. To complete Blue Streak as a launching vehicle would cost (say) £45 million, and the cost of adding Black Knight as a second stage might be estimated at £20 million. Thus, Britain could have available a space launching vehicle, comparable with those currently available in the U.S.A., at a further cost of the order of £65 million—little more than a tenth of the estimated total cost of the original Blue Streak weapon system.

It is important that the work on Blue Streak and its ancillary developments should not be discontinued. Such an action would serve no useful economic purpose. Large departments in a number of our major industrial organizations are already heavily committed to this project. It is doubtful if the highly specialized effort which is involved could be usefully or effectively redeployed, except over a long period. Nothing can be lost in maintaining the present effort for the purpose of laying the foundation for a future civil space programme. The alternative of suddenly stopping all this work, might save money on paper, but it would not add effectively to the nation's prosperity.

4.2. While stressing the immediate need to continue with the present development of Blue Streak as a launching vehicle, very careful consideration must be given to the subsequent programme. The main items of the space programme suggested herewith, would be as follows:—

(*a*) A definite project to develop Blue Streak and a modified Black Knight as a satellite launching vehicle. This would be in addition to the expansion of existing work on satellite tracking and orbit analysis, and a vigorous prosecution of the project to launch British instruments in the American "Scout" rockets.

(*b*) A later project to develop improved and more powerful second and third stages for a modified Blue Streak. This could at least double the payload of this vehicle.

(*c*) A detailed feasibility study of communications satellites, including an examination of their commercial and military significance. (See the Appendix.)

(*d*) The design of equipment and techniques for communication, telemetry and navigation in space, including the provision of power sources.

(*e*) A gradually developing programme of research on hypersonic winged vehicles and their use for controlled re-entry into the atmosphere.

(*f*) A modest programme on space medicine, *i.e.*, on the problems of man in space.

(*g*) A programme of research and development on new propulsion systems, such as the nuclear rocket and electrical (ion and plasma) rockets, possible synthetic metastable propellents of great energy (based on "active" atomic species, etc.). This would be a very long-term programme, developing gradually over the next decade or more.

4.3. On the initial assumption that Blue Streak is continued as a satellite launcher, it is believed that a significant programme as outlined above could be made for a further annual expenditure rising within 5 years to £20 million and being maintained thereafer at this approximate level. The corresponding deployment of technical manpower (in addition to the Blue Streak teams) would rise to about 1000 graduate scientists and engineers (drawn from a variety of disciplines), with supporting technicians, industrial labour and facilities.

5. CO-OPERATION WITH THE COMMONWEALTH AND EUROPE

5.1. An important part of the overall facilities already exist in the launching and tracking facilities at Woomera, Australia. It is assumed that Australia would be asked to participate in a space programme because of the special facilities possessed by that country. From this point of view, the programme suggested can be considered to be a Commonwealth enterprise. Indeed, other members of the Commonwealth might also be invited to participate.

5.2. Another possibility exists for spreading the load, both in terms of finance and industrial and scientific effort, namely partnership with our sister nations in Europe. There exists already a number of co-operative projects in nuclear science and engineering which are functioning in a most effective manner.

It is suggested that, in astronautics, we should recognize this new trend in Europe from the start and think in terms of a European space project rather than a U.K. programme. The importance of doing this lies in the fact that, in terms of industrial and scientific resources, Europe would be able to compete on equal terms with the U.S.A. and U.S.S.R. Indeed, in the matter of talent and special skills Europe might well have advantages over America and Russia.

If the principle of European collaboration is accepted then by means of licence agreements European facilities could be brought into use on Blue Streak. The U.K. could use its existing facilities and contribute a reasonable proportion of the annual budget for the joint programme. In the early stages of the work the U.K. could also manufacture Black Knight and Skylark rockets for a joint atmosphere and space research programme, the cost of the vehicles and operations being shared in an appropriate manner.

A joint European space programme would extend to the following activities:—

(i) Co-ordinated research and development extending over a number of appropriate establishments in Europe.
(ii) Manufacture of components and assembly of vehicles in various European factories.
(iii) Joint operation of test facilities such as Spadeadam and launching sites, *e.g.*, Woomera.
(iv) Division of the programme into a small number of projects. Each project would be centred at some European research establishment and would be run there by an international staff.
(v) There would a joint Board of Directors, including representatives from all the participating countries and from each of the projects, that would direct the overall programme.

6. RECOMMENDATIONS

British participation in space activities should be significantly increased and serious consideration given to the possibility of a co-operative programme with Europe.

The programme should be planned courageously for long-term objectives. Reasonable continuity in the effort involved should be guaranteed, so that workers of adequate calibre will be attracted.

The prevention of a decline in the U.K.'s standing in this technological world can be accomplished if, and only if, our technical effort is expanded in areas of a long-term and adventurous nature. One of the most promising of such areas is astronautics.

APPENDIX

COMMUNICATIONS SATELLITE

GENERAL

The Communications Satellite is one of the applications of Astronautics to peaceful purposes which will be of real commercial value in the next 5 to 10 years. Launching of such a satellite with a Blue Streak/Black Knight two-stage rocket system and possibly a small third stage solid rocket is considered entirely feasible. Payloads up to 1500 lb. could be obtained in the lower orbits.

The commercial value of such a project is underlined by the fact that a round-the-world twin cable, of which each part carried seventy uni-directional speech channels would have an installation cost of £88,000,000 and have a life of about 25 years.

A three satellite system could give a more widespread service at a competitive cost, once the early development difficulties had been overcome and provided the lifetime is at least a year. Much of the development work has already been paid for on Blue Streak.

Two main systems are under consideration in America. Firstly, the passive balloon type satellite about 100ft. in diameter, which is, of course, inflated when outside the atmosphere; this reflects radio signals and being omni-directional with no transmission system of its own, is a fairly short range device. It must therefore move in a close orbit, having a high velocity relative to the Earth. The low altitude and short time over any one area gives a very restricted coverage and hence, a large number of these satellites would be required. Secondly, there is the active satellite, having a power supply and transmission system; this can operate at a much greater altitude and three such satellites would achieve almost world wide coverage, excluding uninhabited polar regions. Inter-Continental television is a third possibility, but close orbit satellites would be needed to avoid a prohibitive power requirement.

The Americans are known to be very active on these new systems of communication. The Russians are no doubt also at work. The first successful satellite system may well achieve a world-wide monopoly of enormous commercial value, which could even oust the present cable system. Urgent action is needed to counter such a monopoly, and if Blue Streak were completely abandoned, there would be little possibility of British participation at some later date.

ORBITS AND PERTURBATIONS

Recent British research has been devoted to the active high altitude satellite. Most orbits are "perturbed" (or displaced) in the course of time by the Sun, the Moon and the non-spherical shape of the Earth, the last mentioned being by far the most important effect. In choosing an orbit, therefore, it must be ensured that perturbations are foreseen and used to advantage.

The second requirement is to provide adequate coverage, *i.e.*, the satellite must be in the right place at the right time to provide lines of sight to both transmitting and receiving stations. This is dealt with later under the heading —"Coverage." Much investigation has been carried out on the 24-hr. circular equatorial orbit with an altitude of 22,300 miles. This has the major advantage that a satellite can remain apparently stationary above a point on the Equator. The great distance from the Earth has, however, many disadvantages. Firstly, a high transmission power is required in the satellite. Secondly, the launching is a difficult problem, requiring three or four stages, and a ratio of launching weight to final weight in orbit of about 400 : 1. Furthermore, great accuracy is needed. The first two or three stages have to accelerate the vehicle to about 6½ miles/sec. with a subsequent fall in speed to about 1 mile/sec. when nearing the final orbit and a final precise acceleration to 2 miles/sec. into the orbit. For these reasons, a nearer orbit seems highly desirable although the rotation relative to the Earth calls for tracking by a ground antenna system. As already mentioned, too close an orbit gives inadequate coverage and as a compromise, some research has been devoted to elliptical orbits which operate mainly in the apogee region. The orbital times would, in general, be an exact sub-multiple of a day so that the satellite would appear in a known position at a regular known time of day.

STABILIZED PLATFORMS

In order to economize in power the satellite must have a ratio antenna which emits a beam towards the Earth or ideally towards the receiving station. This directional transmission calls for a stabilized platform which maintains the beam in a "downwards" direction. No simple gyroscope would be effective as the line of transmission, if downward at one point in the orbit, would be upwards at another point which was diammetrically opposite. The probable means of stabilization is an infra-red detection system looking at the Earth's horizon and signalling the required direction of pitch or roll to an electrically driven flywheel mechanism or other control system. This, of course, implies extra weight but is far more economical than the provision of extra power to cover omni-directional transmission.

POWER SUPPLIES

The power supply required is one which can last for at least a year with no replenishment or maintenance. Furthermore, the ratio of electrical output to weight must be as large as possible. There are two obvious alternatives, firstly, the solar cell which derives energy from the Sun and can charge a battery to maintain continuity. This system, may however, involve another stabilization problem as the solar cells must be kept in position, relative to the Sun. An alternative is the use of a ratio isotope as a source of heat. Electricity may be generated without rotating parts by applying the heat directly to a thermocouple. The "S.N.A.P." generator is quoted as producing 3 W for 6 months for a weight of 10 lb. The solar cell is probably lighter for a given output but against this the ratio isotope can operate during the hours of darkness and thus avoid storage facilities.

The power requirements for a communication satellite will depend on the number of channels, the satellite orbit, the operating frequency and on the size and nature of the ground-based and satellite antennae. The following figures indicate the radiated and primary power requirements for 70 channels, an elliptical orbit of apogee 10,000 miles approximately, carrier frequencies of 1000 or 2000 Mc/s 30 ft. or 100 ft. radio telescope type parabolic ground entenna and a satellite parabolic antenna of 4 ft. aperture.

Size of ground antenna	Frequency	Communications 1 Mc/s. bandwidth		Television 5 Mc/s. bandwidth	
		Radiated power	Input power	Radiated power	Input power
30 ft.	1000 Mc/s.	2kW.	10kW.	10kW.	50kW.
30 ft.	2000 Mc/s.	400W.	2kW.	2kW.	10kW.
100 ft.	1000 Mc/s.	200W.	1kW.	1kW.	5kW.
100 ft.	2000 Mc/s.	40W.	200W.	200W.	1kW.

The antennae beamwidths would be as follows:—

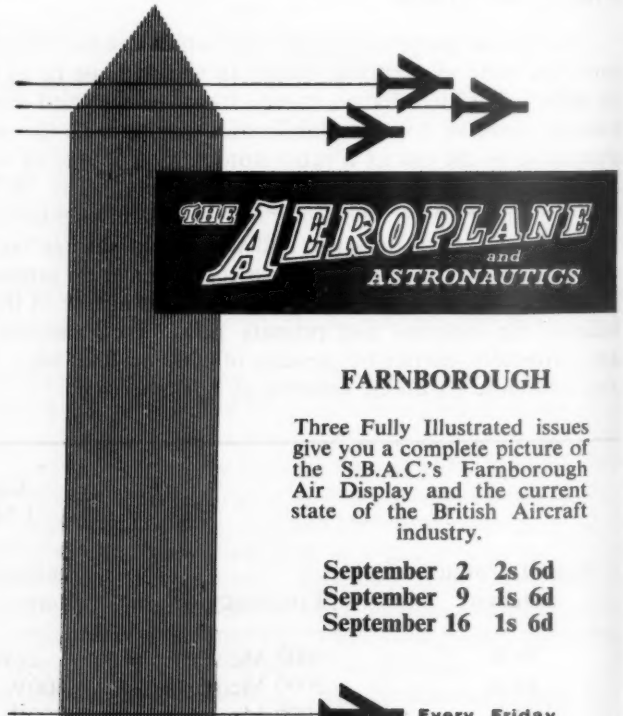
	Size	Frequency	
		1000 Mc/s.	2000 Mc/s.
Ground antenna	30 ft.	2·3°	1·15°
	100 ft.	0·68°	0·34°
Satellite antenna	4 ft.	17°	8·6°

COVERAGE

It has already been shown that the increase, with distance, of power required and the launching weight, form an upper limit to the height above the Earth at which a satellite can operate. Similarly coverage provides the lower limit and this is thought to be not less than 10,000 miles altitude for operation in the equatorial plane, in conjunction with transmission from the Northern latitude of England.

The line of sight from transmitting or receiving station to the satellite must be at least 7½° above the horizon. Thus an observer at Greenwich cannot see the equatorial plane even looking due South except at a considerable distance from the Earth. The real problem, however, is to place a satellite so that it can "see" the receiving and transmitting stations simultaneously, for the longest possible period. The period during which the satellite remains effective clearly depends on the differences in longitude and latitude between transmitting and receiving stations.

It is believed that using a single satellite relay we should be able to cover 90° longitude. If, however, we need to go to the limit and cover 180° longitude, the best method is to transmit via a satellite to a relay station on the ground at about 90° longitude. The process could then be repeated to cover the remaining 90° longitude. A ground relay station would be required 90° west of Greenwich (say British Honduras or Winnipeg) and another one in an easterly direction (say the Andaman Islands). By this means the three satellites could probably provide a fairly general coverage but a precise statement would depend on details of the communications requirement. An alternative system has been suggested which transmits to one satellite which in turn transmits to a second satellite and so back to Earth. This proposal is believed to be impracticable because of the power requirement for the first satellite.


THE AEROPLANE and ASTRONAUTICS
FARNBOROUGH
Three Fully Illustrated issues give you a complete picture of the S.B.A.C.'s Farnborough Air Display and the current state of the British Aircraft industry.
September 2 2s 6d
September 9 1s 6d
September 16 1s 6d
Every Friday

Co-operation in Space-Research*

By ARNOLD W. FRUTKIN†

Explorer VII, launched on 13 October, 1959, is still emitting signals. Direct reduction of data by the World scientific community has been made possible by the release of telemetry codes by N.A.S.A.

National Aeronautics and Space Administration

One may well ask why it is that N.A.S.A., while heavily committed to a difficult and ambitious programme of space research, nevertheless seeks to engage in co-operative efforts with other nations. My first remarks suggest at least two reasons:

First, man's first ventures into space were taken in the context of international co-operation in science—as part of the programme of the International Geophysical Year. The I.G.Y. operation captivated men's minds. It has achieved a dynamism which almost demands that we continue to work within the same sort of framework.

Second, the technology of operations in space research virtually requires global efforts. No country can be satisfied with tracking and telemetry efforts which are restricted to its own borders. Even the Soviet Union has requested the services of tracking stations located in South America, in South Africa, and in Australia in order to cover the movements of its satellites over the Southern Hemisphere. Soviet scientists have also made important use of the big radio-telescope at Jodrell Bank in England.

But there are other considerations. We recognize that scientists in all countries can make important contributions to the theory and practice of space research.

Ultimately, more ambitious efforts to push our knowledge ever further into space will become so costly and complex that the burdens will be too great for any one nation to carry. It will be desirable to pool energies and contributions as well as costs.

Above all, perhaps, we know that space is inherently international in character. It is already a widely accepted principle that no one nation should appropriate to itself regions or natural bodies in space. There is strong feeling everywhere that we must not extend cold wars and armaments competitions into the vastness of space. We, for our part, hope to demonstrate by the openness of our programme and our readiness to participate in co-operative projects, that we subscribe in fact as well as in word to these principles.

Each of the considerations which I have just mentioned was reviewed by the Congress of the United States when, in the spring of 1958, it debated the establishment of a civilian space agency in the United States. The records of these Hearings show very clearly how conscious our legislators were of every one of these points. So, it is not surprising that the Congress wrote into the Act establishing N.A.S.A. that one of its purposes should be: "Co-operation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof. . . ." N.A.S.A. has accepted this objective not as a pious pronouncement but rather as a substantive obligation.

In order to provide for aggressive support of international objectives within N.A.S.A. in response to the Congressional mandate, the Administrator established the Office of International Programmes. It is the function of this office to generate, to encourage, to co-ordinate, and to provide necessary supporting services for N.A.S.A.'s co-operative activities. I should like now to tell you what principles we mean to follow in co-operative programmes. Then I propose to tell you something about those programmes in which we are already engaged.

We feel that programmes of international co-operation should be substantive in character, contributing toward the technical and scientific objectives of space research.

* *From an address given before members of the Inter-American Defence Board in Washington, D.C., on 16 February, 1960.*

† *Director, Office of International Programmes, National Aeronautics and Space Administration.*

This suggests that the programmes themselves should grow out of, or be capable of integration with, N.A.S.A.'s own operating and research programmes. But we do not wish to suggest to other nations' scientists what projects or programmes they should adopt, or, indeed, that they should enter into space research at all. If co-operation is desired, however, we are eager to discuss the possibilities. In such cases, we believe that consideration should be given to specific, limited projects, for it is too early in this new science to chart broad general programmes. The essential criterion should be that the projects have scientific or technical validity. We would hope that proposals would represent experiments or other projects which we ourselves would wish to carry out if they were not to be done jointly.

Generally speaking, we cannot at this time consider programmes which would involve an exchange of funds. Rather, each nation should be able to support its own contribution. However, it is not necessary that contributions be of equal scope and magnitude. Beyond these particular points, it goes without saying that the free exchange of information, and especially the results of our experiments, should be made available to the scientists of all nations. To this end we support the activity in the United Nations regarding the peaceful uses of outer space. Similarly we are, through our National Academy of Sciences, giving full support to the International Committee on Space Research (COSPAR), one of the permanent offshoots of the World Committee for the I.G.Y.

Types of Programmes

I should like to tell you now of the types of international programme which N.A.S.A. is already conducting. It is convenient to distinguish four basic types of international activity in which N.A.S.A. is engaged:

(1) Operational. This involves the acquisition and/or operation of tracking and telemetry stations and services as necessary to meet operating requirements for a global range.

(2) Informational. This category includes the dissemination of *advance* information to foreign scientists so they may prepare to utilize U.S. space satellites in independent ground-based experiments of their own. It also includes the dissemination of *results* of experiments for the information and benefit of scientists everywhere.

(3) Joint.—This category includes projects, experiments and exchanges of mutual interest and advantage between U.S. and foreign scientists.

(4) Personnel Exchanges and Training. This refers to programmes which provide close working relationships for foreign scientists in N.A.S.A. laboratories.

Let me describe each of these four types of programmes in more detail.

Operational Programmes

N.A.S.A.'s foreign operations indicate how widespread our international activities have already become. Co-ordinated space probe tracking activities are conducted or are about to be conducted in a total of nineteen countries. Based in our own hemisphere, these now extend to Africa, and the Pacific while additional stations are in prospect in the United Kingdom and Canada.

The backbone of these tracking activities are the radio and optical stations established in South America. (The optical stations, established by the Smithsonian Astrophysical Observatory, are operated now for N.A.S.A. under grant.) In Chile, Equador and Peru, these stations are operated jointly with technicians of these countries. In every case, the governments concerned have generously entered into agreements for the continued operation of these stations.

Other Minitrack and Baker-Nunn Camera stations are operated in South Africa and Australia. Two new Minitrack stations—designed to extend our network latitudinally—are planned in Newfoundland and England,† subject to the approval of the Canadian and British governments.

This basic operating network is supplemented in three instances by contract or grant arrangements. The largest steerable radio-telescope in the world, at Jodrell Bank in England, has contributed invaluable tracking services during the past year under contract with N.A.S.A. Grants for tracking and telemetry services, together with necessary U.S. equipment, have gone to the University of Heidelberg in West Germany and to the Radio Research Laboratories of the Ministry of Posts and Telecommunications in Japan.

At the present time, N.A.S.A. is engaged in establishing a special network of tracking and data acquisition stations abroad in connection with Project Mercury, the first step in the U.S. manned satellite programme; government-to-government negotiations are in progress for sites in Australia, Bermuda, the Canaries, Canton Island, Mexico, Nigeria, and Zanzibar. At least two of the Mercury stations will be operated by nationals of the host country. Additional participation will be possible to the extent that qualified personnel become available.

This special network is required because of the orbital inclination which the Mercury capsule is designed to take. Tracking and telemetry stations are more closely spaced for this programme than for any other yet conducted by N.A.S.A. This will permit virtually continuous monitoring of the physiological reactions and condition of the Mercury astronaut. Necessary decisions may then be made at the earliest possible time in the interests of the astronaut's safety.

Finally, as our efforts turn increasingly toward deeper

† *To be established at Slough, Bucks.*

probing into the reaches of our planetary system, we will require specialized stations with high capabilities for very long range tracking. A network of radio telescopes for this purpose is being established. We hope to supplement installations now within our own borders by locating new 85-ft. steerable "dishes" for the tracking of deep space probes in the southern Pacific and in southern Africa, with the permission and participation of the governments concerned.

As I have said, nineteen countries or political entities are involved in these network arrangements. It is clear, then, that N.A.S.A.'s global tracking range is truly international in character and that a very considerable input is provided by technicians and scientists abroad. In addition, the land for most of the station sites has been made available without cost.

These far-flung activities of N.A.S.A. help to broaden scientific interest, participation, and contribution in the exploration of space. It is N.A.S.A.'s desire to encourage further participation by nationals of the countries in which tracking sites are located.

Informational Programmes

N.A.S.A. continues the launching announcements and data exchanges which were instituted during the International Geophysical Year. The launching of sounding rockets is reported in brief flight summaries which are filed with World Data Centre A (Rockets and Satellites) at the National Academy of Sciences. The Academy then distributes this material to the other World Data Centres in England and the Soviet Union. At six-month intervals, the material is catalogued for the information of the scientific community.

Announcements of the launching of satellites and space probes are made routinely within a few hours through SPACEWARN, a special world communications net established during the I.G.Y., as well as in the Press. These announcements provide scientists with orbital characteristics, satellite or probe weight, types of instrumentation and experimental objectives.

Results of experiments are published in the recognized scientific journals and distributed also through the World Data Centres. Techniques for interim cataloguing and periodic notification of available results are now under joint study by N.A.S.A. and the National Academy of Sciences.

N.A.S.A. is also participating extensively in scientific symposia, in many ways the life-stream of international scientific exchange. During 1960, N.A.S.A. scientists and technicians have attended, or will attend and contribute to, meetings in Nice, Tokyo, Helsinki, Ottawa, Copenhagen, Madrid, Buenos Aires, and other cities abroad as well as here in the United States. Potentially the most significant of these symposia is the United Nations Space Conference. N.A.S.A. is preparing to play a central role in organizing the U.S. contribution to this hopeful exchange among pioneers in space from all nations.

The methods, objectives, and standards of international exchange of data were reviewed by COSPAR last month in Nice. It is of some interest that this meeting resulted in renewing the understandings for scientific exchange which had been established during the I.G.Y. In addition, these understandings were enlarged in at least two respects. The Soviet scientists have now agreed to provide the orbital elements of the trajectories of their satellites so that scientists everywhere can compute the appropriate look angles needed to locate these satellites by radio or optical means from any location on earth. In the past, the Soviets provided this information only for specific locations on the globe. In addition, it has been agreed that launching nations will hereafter give advance notice of satellite launchings where the orbital inclination, the power output, the radio frequency to be used, or the opportunities for observation are significantly different from those in past satellites.

N.A.S.A. seeks not only to comply with but to go beyond the exchanges already agreed on internationally. Even before the COSPAR meeting, steps were taken to provide the world scientific community with an opportunity to participate in a future U.S. experiment in accordance with local capabilities and interests. The experiment is Project Echo, the launching of a 100-ft. inflatable, aluminized sphere which will serve as a passive reflector for communications experiments and will also permit studies of atmospheric drag. The details of the experiment have been disseminated not only in the United States, but also to COSPAR and individual scientists abroad who may be interested. With this advance information, foreign scientists may prepare the necessary equipment and arrange for such ground-based experiments as are feasible. This procedure

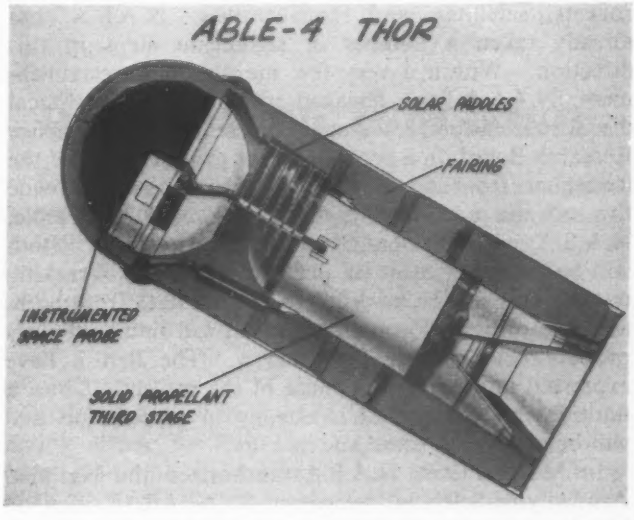


Diagram of the solar probe, Pioneer V, as it appeared in the nose of the Thor-Able launching vehicle. Jodrell Bank—co-operating with N.A.S.A.—was able to communicate with the probe up to a distance of 22·5 million miles.
National Aeronautics and Space Administration

will serve as a pattern for future advance notification where appropriate—in the interests of broad participation, maximum utilization, and, not least, optimum benefits for all.

In the same way, N.A.S.A. has notified the international scientific community that the telemetry calibrations for Explorer VII will soon be available to them to use for direct reduction of the data provided by that satellite.

Joints Projects

Perhaps the most interesting of the possibilities for international co-operation is participation by the scientists of two or more countries in the design of experiments and in the preparation of payloads for rockets, satellites, and space probes. N.A.S.A. has already taken a number of significant steps in this direction. Within a very few months of its establishment, N.A.S.A. was engaged in preliminary technical discussions with representatives of the Canadian Defence Research Board on a proposed joint project to sound the ionosphere from above. The Canadians will also provide the antenna and satellite shell required. Meanwhile, N.A.S.A. will develop a fixed-frequency sounder. Both will be placed in orbit by the United States. Tracking installations will be modified to acquire data from both, and a co-ordinated ground-based net will simultaneously probe the ionosphere from below. The British have expressed interest in this phase of the project. Thus, a multi-lateral experiment is already in preparation and will be conducted sometime in 1961.

In March, 1959, N.A.S.A. authorized the National Academy of Sciences' delegate to COSPAR to offer, on behalf of the United States, to place in orbit individual experiments or complete satellite payloads prepared by scientists of other nations. Because the closest possible collaboration is desirable in such efforts, it was stated that the experimenters were welcome to work together with American teams in the development of their projects.

In July, the United Kingdom set a team to the U.S. under Professor H. W. S. Massey to discuss a British proposal within the framework of N.A.S.A's offer to COSPAR. It was tentatively agreed that British scientists, over a two- to four-year period, would instrument perhaps three satellites for launching, probably by means of N.A.S.A.'s Scout vehicle. Each nation assumes responsibility for its own contribution. Specific proposals for four experiments to be flown in the first joint satellite were agreed upon last month. They will involve studies of solar radiation, electron density and temperature, and cosmic radiation. These will permit unique correlations of the on-board experiments themselves as well as between these and ground-based or air-space experiments. An exchange of notes at the governmental level will formalize this arrangement. The proposed experiments were communicated to COSPAR in January and have been endorsed by that Committee.

The U.S. offer to COSPAR in March, 1959, was followed up during September and October, 1959, by discussions abroad with scientists of a number of European countries. These discussions were undertaken by Dr. Hugh Dryden, the Deputy Administrator of N.A.S.A., in company with Dr. Homer Newell, the Deputy Director of the Office of Space Flight Programmes, and myself. The discussions were directed toward those countries which were known to have established, or to be considering establishment of, national space centres or committees. We wanted to learn something of the development of space interests abroad and to offer, without any suggestion of interference, to discuss co-operative programmes if, and when, the space interests in each country became organized and endorsed by their governments or major scientific institutions. We described (1) the organization of space activity in the United States; (2) N.A.S.A.'s special interest in international co-operation in accordance with the National Aeronautics and Space Act of 1958; (3) the progress already made in programmes of co-operation; and (4) the kind of co-operation we thought desirable. We said also that co-operative programmes might ultimately be formulated at the diplomatic level, if required by reason of magnitude or content, but that in all cases technical discussions on an informal basis should precede governmental agreement. Quite frankly we feel this is necessary to ensure that co-operative programmes are technical in character and that any commitments are acceptable to our operating people. Finally, it was proposed that COSPAR be informed of the nature of any agreed scientific programmes, so we might benefit from the interest, constructive comment, and auspices of the international scientific community.

The organization of space interests is almost everywhere in early stages. Nevertheless, in addition to the United Kingdom and Canada, Australia, Belgium, France, Japan, Italy and Sweden are known to have established national space committees. (The U.S.S.R.,

of course, has had a space commission in existence for some years.) While definitive programmes have not yet been announced, and informal discussions suggest that relatively limited programmes are in view, there appears to be a strong interest in co-operative programmes in the European and Pacific nations. In fact, only co-operation will make possible programmes extending beyond relatively limited sounding rocket projects. This is due, in large part, to the very substantial financial requirements involved in more ambitious efforts.

In any event, it is becoming increasingly evident that the N.A.S.A. offer to COSPAR has generated considerable discussion abroad, with the result that interest in co-operative programmes has been expressed formally or informally on behalf of scientists in Argentina, Australia, Belgium, France, Japan, Israel, Italy, New Zealand, Sweden, the United Kingdom and West Germany. The interest has been both formal and informal and ranges from requests for sounding rockets, or the exchange of scientific personnel, to full-scale preparation of instrumented satellites.

For example, the Australians have proposed that they prepare instrumentation to study very low frequency emissions above the ionosphere in the regions of the lines of magnetic force. The instrumentation would be launched in rockets or satellites by the United States. There is in prospect also a "multi-lateral" rocket sounding programme. The U.S. hopes to purchase British Skylark rockets for which the Australian launching range at Woomera is fitted and to instrument them for the necessary experiments, the rockets themselves to be launched by the Australians. N.A.S.A. has expressed interest in every case and has invited specific proposals where these have not been provided. N.A.S.A. considers, therefore, that a very wide range of co-operative activities is in prospect and it is the Administration's intention to encourage these most energetically.

N.A.S.A. has not confined its interests in co-operation in space research to the West. The possibilities of co-operation with the U.S.S.R. have been explored as opportunity presented. An extensive discussion of preliminary nature was conducted in mid-November with the Chairman of the Soviet Commission for Inter-Planetary Travel, Professor Sedov, and another member of the Commission, Academician Blagonravov, during the visit of the U.S.S.R. delegation to the American Rocket Society meeting here in Washington. The Soviet scientists then expressed willingness to consider some form of co-operation in space activity but stated their belief that such co-operation would have to proceed "step-by-step." The only step which they were at that time willing to discuss was the Space Conference under U.N. auspices which had been proposed by their representative in the United Nations. More recently, the N.A.S.A. Administrator, Dr. T. Keith Glennan, in an address before the Institute of World Affairs in Pasadena on 7 December, 1959, offered the services of the Project Mercury tracking network to the Soviet Union when, as, and if, it should conduct a man-in-space programme. Dr. Glennan then stated that data could be acquired and transmitted in its raw state to the Academy of Sciences in Moscow. He stated also N.A.S.A.'s readiness to utilize Soviet equipment should special recording or data read-out be required. The offer was promptly transmitted through the National Academy of Sciences to the Soviet Academy of Sciences. While no response has yet been received, N.A.S.A. plans to continue exploration of possibilities for co-operation with the Soviet Union in projects of mutual interest as occasion permits.

Personnel Exchanges and Training

In order to provide an opportunity for foreign scientists to develop their interests and capabilities for space research, N.A.S.A. has established post-doctoral and senior resident research associateships, administered by the National Academy of Sciences. These associateships provide stipends beginning at $8000 per year. While not intended primarily for foreign nationals, thus far five scientists have been accepted for such associateships from abroad. The countries from which they come include Japan, India, New Zealand and Denmark.

N.A.S.A.'s preferred method of operation in connection with joint projects, as well as specific proposals by foreign space committees, will operate to increase the number of foreign scientists working in U.S. space laboratories. Of course, considerations of operating efficiency in the building of our own teams requires that discretion be used in accommodating training and fellowship personnel. At present N.A.S.A. does not have funds, outside of the associateship programme, to make available for the travel and subsistence of scientists. Where, however, their own governments or scientific institutions provide such funds, N.A.S.A. will make every effort to provide the laboratory support and guidance possible.

One Saving Omission

"Notwithstanding anything to the contrary contained herein this Policy does not cover loss or damage directly or indirectly occasioned by, happening through or in consequence of war, invasion, acts of foreign enemies, hostilities (whether war be declared or not), civil war, rebellion, revolution, insurrection, military or usurped power, riots, civil commotions or confiscation or nationalization or. . . ."

Quoting all this from Lloyd's Fire Policy, a fourth leading article in *The Times* adds: "Desperately the reader scans the list, hoping to find some quarter from which peril is not apprehended. But there is only one omission from this compendium of calamities which can bring him any solid comfort: if Mon Repos is burnt to the ground by creatures from Outer Space, he will still be able to claim."

Reviews

Rockets and Satellites Work Like This. By John W. R. Taylor. Phoenix House Ltd., London, and Roy Publishers, New York. 71 pp. 60 illustrations. 9s. 6d.

This slim book is one of the Publisher's *Science Works Like This* series. I think it may fairly be described as a rocket and astronautics primer suitable for all newcomers between the ages of eight and eighty. I found it remarkable for the amount of information contained in so few pages and its simplicity of explanation. The author wastes no time on fanfares: as a result, all the essentials are there without rhetorical padding. It speaks much for the author's literary skill and grasp of his subjects that compression has been achieved without desiccation . . . and without those errors which are so easily engendered by simplification. In addition, the illustration, by that well-known astronautical artist John W. Wood, are excellently done.

The book carries the reader factually from the Chinese beginnings of rocketry up to *Sputnik III*, and mentions the Russian solar satellite "*Planet III.*" In doing so, it also sketches astronautical history and deals with missiles and guidance systems of German and American origin. The latter part of the book discusses future possibilities, including manned rockets and planetary and stellar probes. Finally there is a short dissertation on careers in rocketry. From this it becomes manifest that the book is primarily intended for juveniles. However, that is no reason why it should be avoided by adults. On the contrary, I recommend it to anyone in need of a mathematically painless introduction to rocketry and astronautics.

H. E. Ross.

Astronomy. By T. G. Mehlin. 392 pp., illustrated. John Wiley & Sons, New York (London, Chapman & Hall). 1959.

Many books about popular astronomy have appeared in recent years, but this new volume, by the Field Memorial Professor of Astronomy at Williams College, U.S.A., is welcome in view of its high standard. The text is admirably clear, and is detailed enough to be useful to the student as well as to the beginner.

In works of this sort it is conventional to begin with the Solar System, and then move on to the stars and galaxies. Professor Mehlin has not followed this precedent. After a preliminary chapter dealing with instrumental equipment, he plunges straight into "The Life Story of a Star," "Stellar Distances and Motions," "The Sun," "Binary Stars," "Intrinsic Variables," "Galaxies" and "Our Galaxy." These eight chapters are the most technical in the book, and probably the most valuable. The Solar System is described in the last 140 pages; it is worth noting that Chapter 12 is entitled "The Earth's Satellites," and the first few orbital vehicles are included. A few years ago it would indeed have seemed strange to find such material in an astronomical work; nowadays, no such work would be complete without it.

The serious student will welcome Professor Mehlin's way of arranging his book, but it has some disadvantages for the beginner, and one example will suffice to emphasize this. Stellar spectroscopy comes within the first 60 pages, and the reader is introduced to matters such as the Hertzsprung-Russell Diagram. Yet it is not until page 299 that he will find a figure illustrating why the Moon shows its monthly phases; similar very elementary material comes very late in the book. It might have been wise to include a preliminary chapter, making such points and so putting the layman completely "in the picture" before dealing with more complicated stellar topics.

However, this is a matter of opinion, and in any case there can be no doubt that the author has produced a really excellent book. It covers a great deal of ground, and is packed with information; fortunately the writing style is so clear that there is no impression of crowding, and the reader who follows the text right through will gain an accurate, balanced knowledge of the fundamentals of astronomical science. Each chapter ends with a list of "practice" questions, and these are valuable to the student.

The illustrations leave little to be desired. There are plenty of line diagrams, and also numerous photographs, all of which are well reproduced. The print and binding are equally satisfactory, and the few misprints which have been noticed are too minor to be worth listing.

Enough has been said to show that this book may be thoroughly recommended, particularly to the reader who means to take astronomy seriously.

Patrick Moore.

Astronomical Photography at the Telescope. By Thomas Rackham. Faber & Faber. 1959. 232 pp.

Dr. Steavenson, one of Britain's foremost amateur astonomers, writes a foreword to this book. As he mentions, sooner or later the owner of any astronomical telescope will feel an urge to make a permanent record of the spectacular views seen through the eyepiece. Mr. Rackham is a first-class observer and being highly practical as well as technically competent, he has succeeded admirably in this task. The book clearly shows that he has, in addition, a real talent for lucid and helpful writing and he always keeps in mind the needs of the amateur with limited resources.

Practically all the snags that can arise are dealt with—obviously from personal experience.

An excellent description of the photographic process gives the reader a sound basis to help in achieving high resolution photography at the telescope. There are chapters on developing, printing, enlarging and darkroom equipment, and the several appendices give useful optical, image size and exposure data, as well as a short glossary. All of this is presented in a form calculated to be of much help to the beginner embarking on this fascinating field.

The chapters dealing with telescopes and cameras are naturally loaded with the authors own, mostly home built, equipment. This is described and illustrated in full detail, and the efficacy is evident in the considerable number of astronomical (mostly lunar, planetary and solar) photographs, which are all taken with the authors modest 6-in. reflecting telescope.

Satellite photography is not specifically dealt with, nor is comet photography or wide field stellar photography. These do not come in the category of photography through the ordinary telescope. However, the techniques described will apply in large measure if appropriate separate cameras are attached to the telescope which is then used to steer them along the proper path.

In the focussing methods recommended by the author he has a tendency to slur over the effects of accommodation, particularly in the youthful eye. Unfortunately this can be large and variable and give rise to appreciable errors both with the authors special design of camera, or with the pre-focussed camera which is sometimes used to replace the eye at the eyepiece. The eyes of the middle-aged are less troubled in this respect; one of the minor advantages of age.

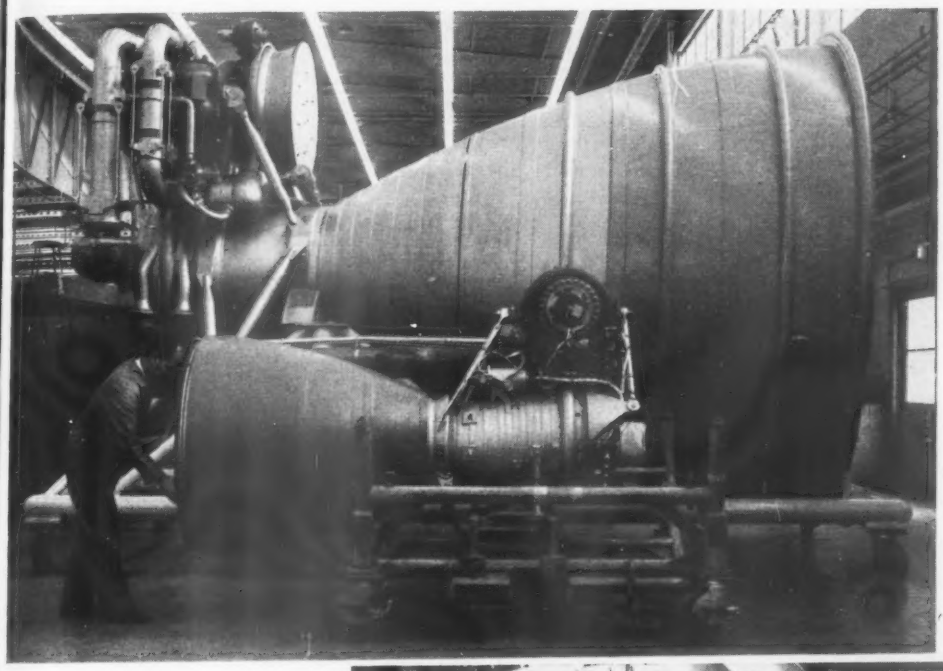
Few errors occur in the book, which is evidence of careful checking. On page 24, the resolving power of the telescope should be given as proportional to the aperture, not to the square of the aperture.

The book will undoubtedly fill a growing need and it can be confidently recommended.

H. E. Dall.

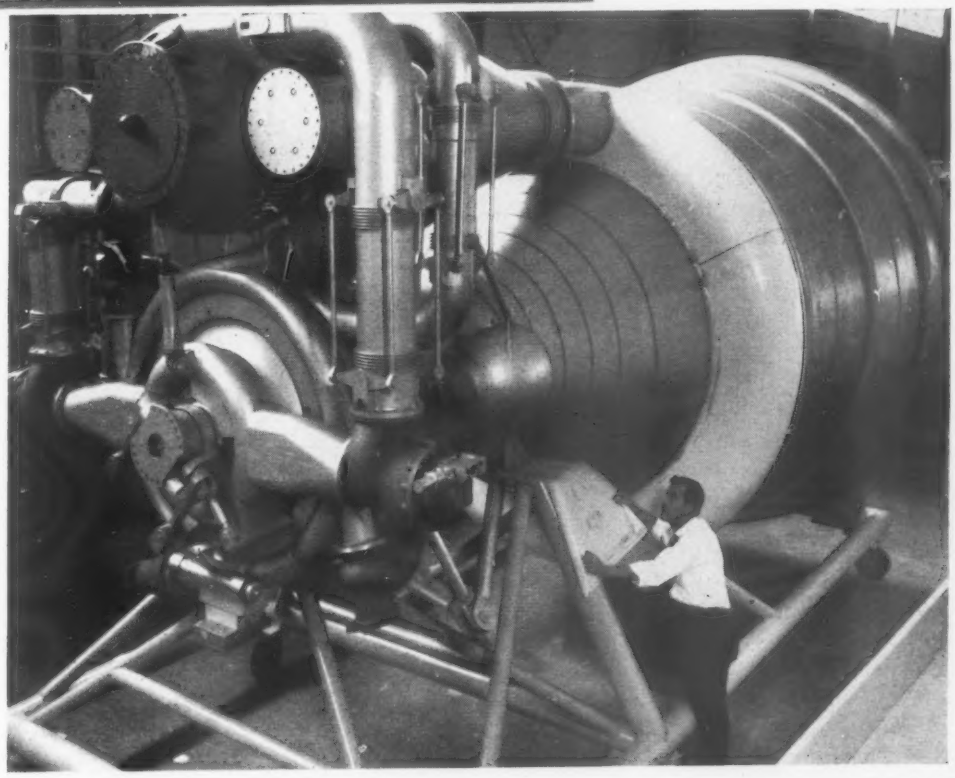
ROCKETDYNE'S MAMMOTH F-1

America's most powerful rocket engine will look much like this full-scale mock-up when it is ready for flight testing in three to four years time. Under development by the Rocketdyne Division of North American Aviation, Inc., since December, 1958, for the National Aeronauties and Space Administration, the single-chambered engine is designed to produce 1,500,000 lb. of thrust. Static tests of the prototype engine are just beginning at Edwards Air Force Base. By clustering F-1 engines, N.A.S.A. eventually expects to obtain thrust levels as high as 6,000,000 to 12,000,000 lb. A multi-stage booster with such thrust could put a manned space-station of 150,000 lb. into orbit at 300 miles, or send manned vehicles to the Moon and return a 10,000 lb. payload.



This picture compares the F-1 engine—seen here in mock-up form—with one of the eight H-1 engines of 188,000 lb. s.t. used in the Saturn booster.

North American Rocketdyne



Size of the F-1 rocket engine can be seen to effect in this view of the mock-up. Note dimensions of the feed pipes which must supply nearly three tons of propellent every second to the combustion chamber.

North American Rocketdyne

Question and Answer

There have recently been reports in the Aeronautical press that some Russian rocket vehicles are launched horizontally along steel tracks instead of vertically as is evidently the case with all the large American rockets. If we give this idea some consideration it can be seen that the horizontal launching does not subtract the pull of gravity from the thrust of the rocket motor, as is the case in the vertical launch. Even if the thrust of the motor is smaller than the mass of the vehicle it will all be employed to propel the rocket horizontally, whilst in these circumstances a vertical launch would never leave the ground.

Is this perhaps why the Russians were able to put tons of equipment into orbit in comparison with the pounds that the Americans achieved in their early launchings?

Does it also explain the superior accuracy of the Russian's shots? The launching rails could be very precisely aligned and used to guide the vehicle so that it starts its trajectory very accurately.

There is no doubt at all that a horizontal trajectory of launching for a rocket is the most economical one possible when taking off from a planet or moon which is without an atmosphere. We may indeed be sure that in taking off from our own Moon a rocket would be tilted over on its side very quickly after take-off, so as to avoid expending energy to lift fuel uselessly against the Moon's gravity. As it is unlikely that a large civil engineering force will be available on the Moon in the earlier days of manned spaceflight a horizontal track on the ground will not be used, and indeed would have to be many miles long in order to permit a manned takeoff at acceptable acceleration. A. C. Clarke[1] has, however, suggested horizontal launchers for firing material which could stand high acceleration into space from the Moon's surface.

When taking off from the Earth's surface the dense atmosphere is of overriding importance. Any attempt at a horizontal trajectory would destroy the vehicle by atmospheric friction long before it could attain anywhere near the 5 miles/sec. velocity needed to get it into an orbit. Of necessity, both Russian and American space rockets take off vertically, piercing the thick lower layers of the atmosphere whilst still moving relatively slowly. The most economical course is then a nice compromise between excessive air friction if the trajectory flattens out too soon, and excessive "g loss" if the vehicle climbs too steeply.

It is generally accepted that the startling difference in payload between the early American and Russian satellites arose simply because the Russians had rather bigger and better rockets. Lately there have been indications that the gap between American and Russian techniques is narrowing.—C. A. Cross.

REFERENCE

1. A. C. Clarke, "Electromagnetic launching as a major contribution to spaceflight," *J.B.I.S.*, Nov., 1950, pp. 261–267.

Satellite Model Re-Entry

National Aeronautics and Space Administration scientists have succeeded in the laboratory in recovering a small test model after a simulated re-entry at Earth-satellite speed.

The satellite recovery experiment on a laboratory scale was accomplished at the N.A.S.A. Ames Research Center, Moffett Field, California, on 27 February. Since that date, N.A.S.A. scientists have been analyzing the results of the test and continuing a series of related experiments.

The experiment was performed in the Ames Atmosphere Entry Simulator, a laboratory device which has contributed valuable knowledge to the solution of the re-entry problem. The simulator consists of a special trumpet-shaped nozzle which accelerates a flow of high pressure air in such a manner that it duplicates accurately the way in which the Earth's atmosphere becomes thinner with increasing altitude. At the widest part of the nozzle, air thins to the very low densities typical of the region where re-entry flight begins. As the nozzle narrows, air density increases to match conditions at every lower altitudes. A model flying through the simulator experiences the same changes in air density and velocity as an actual object re-entering the Earth's atmosphere.

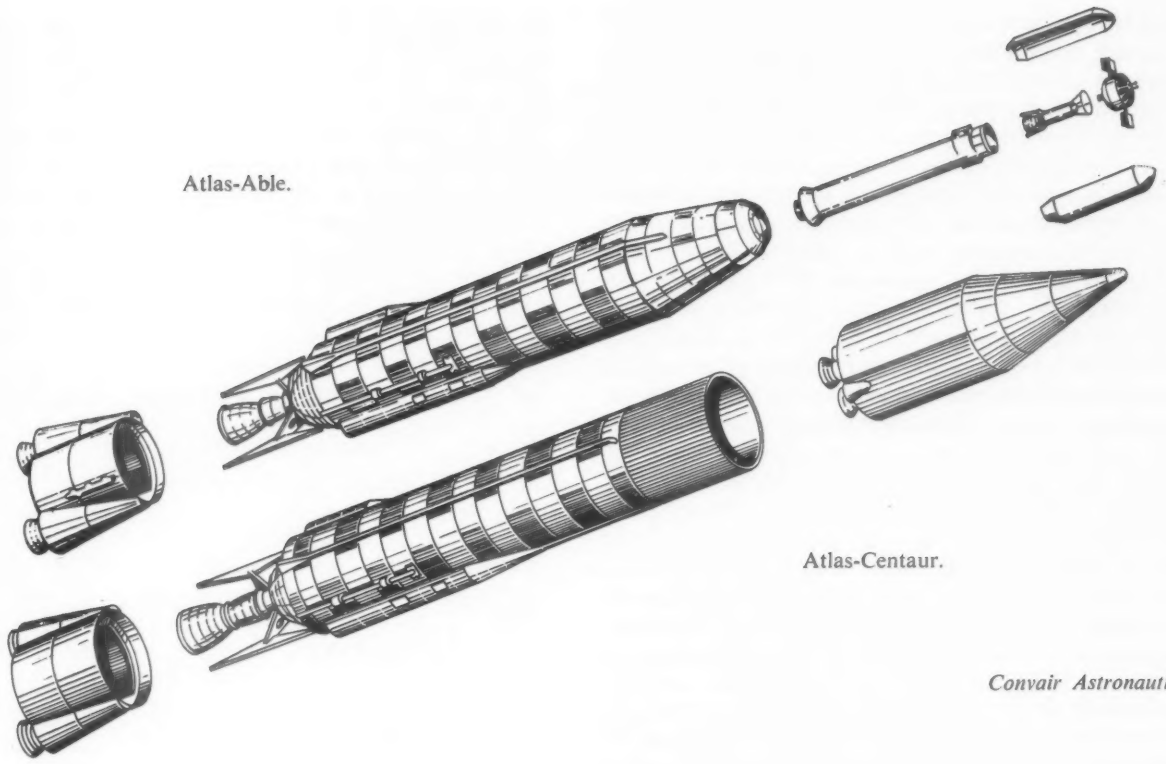
The successfully-recovered satellite model flown through the simulator was made of a plastic material just under $\frac{1}{4}$ in. in diameter. Its nose-shape was similar to that of the blunt forward face of the Project Mercury capsule now being developed for N.A.S.A.'s manned spaceflight programme. The test served to confirm the validity of the type of heat shield selected for Project Mercury by completing re-entry under conditions more severe than the capsule will experience.

A three-stage shock heated gun, using helium as the propellent gas, launched the model at 17,000 m.p.h. Launching energy was produced by a series of shock waves inside the gun's three stages by burning gunpowder.

Optical instruments along the flight path of the model satellite recorded the luminous streak created as it plunged through the air in the simulator. (Meteors make similar streaks as they enter the Earth's atmosphere.) Spark shadowgraph pictures were taken to permit study of the shock wave and wake generated by the flying test object.

The recovered model was carefully weighed and analyzed to discover how much material was lost by vaporization at the extreme temperatures experienced during flight. It was found that well under 5% of the plastic ablation material of which the model was made had been vaporized. Peak temperatures near 20,000° F. occurred in the air just ahead of the model during flight.

The successful satellite recovery test is part of a programme in which N.A.S.A. scientists are trying to reach ever higher speeds under laboratory test conditions. They are now hoping to duplicate in the laboratory speeds typical of spacecraft re-entries from lunar or planetary missions.



Atlas-Able.

Atlas-Centaur.

Convair Astronautics

The N.A.S.A. Space Sciences—4*

Concluding our series on the long-term aims and objectives of the United States civilian space-programme.

ASTRONOMY

Objectives

To determine the spatial distributions of matter and energy over the entire universe, and to understand their cosmological origins, evolutions, and destinies. To observe from above the Earth's atmosphere the spectral distributions of energy radiated from objects in the solar system, in this and other galaxies, and in the intervening space, with emphasis on observations that are prevented or compromised by the absorption, background emission, and refraction of the Earth's atmosphere. To determine and understand the structure and the surface features of the planets. To determine the effects of meteors, radiations and other astronomical influences on instrumented and manned space exploration.

Present Knowledge

The field of astronomy may be broadly divided into five categories: (1) the solar system; (2) the stars; (3) interstellar matter; (4) the characteristics of stellar aggregates, such as clusters and galaxies; (5) the history and evolution of the universe and its various components.

* *Continued from the April, 1960, issue.*

The Solar System

The dark bodies orbiting around the Sun may be classified as planets, satellites, minor plants or asteroids and comets. The nine planets, including the Earth, differ primarily in size and in temperature. The smallest ones, such as Mercury, have too little gravitation to retain any atmosphere, while the larger planets, such as Jupiter and Saturn, have extremely dense atmospheres. Those planets closest to the Sun have, of course, quite high temperatures, whereas the most distant planets are very cold. With respect to the amount of atmosphere and to temperature, Venus, Earth and Mars are intermediate, and these three planets are considered to be the only ones that might naturally support any form of life. Earth may be the only planet on which conditions are so ideal as to favour the evolution of intelligent life. Asteroids and most of the satellites of planets are small bodies, ranging from dust particles to boulders a few hundred miles across. The comets are loose agglomerations of rock and gas that spend most of their time in the far reaches of the solar system and approach the Sun at infrequent intervals. The asteroids and comets are probably the debris left over from the formation of the planets some five billion years ago.

The Stars

It is now known that the stars are gaseous bodies composed of about 75% hydrogen by weight, 25% helium and traces of the remaining elements. Most stars derive their energy from the conversion of hydrogen into helium deep in the stellar interior where temperatures and pressures are extremely high. This energy is transferred to the outer layers of the star by radiation and convection; there the emerging light is affected by the constituents of the stellar atmosphere, producing the observable stellar spectrum. This spectrum, together with independent information concerning the star's luminosity and mass, is the basic datum from which all knowledge of the star's structure must be deduced. A significant stellar characteristic is the fairly well defined correlation between surface temperature, as evidenced by a star's spectrum or colour, and intrinsic luminosity. The form of this temperature-luminosity diagram has yielded much information concerning the nature of stellar atmospheres. From the study of spectra it is found that the chemical constituents are approximately constant from star to star; however, other parameters vary widely. Surface temperatures range from 1500° K. to more than 50,000° K. Stellar diameters vary from less than 0·01 to more than 500 times that of the Sun; masses range from 0·1 to 50 solar masses; and intrinsic luminosities vary by a factor of a hundred million. The outer layers of a star are far from being in equilibrium. This is obvious in the case of the Sun, where sunspots and their accompanying magnetic fields, intense hot spots called flares, and eruptions from the surface, called prominences, indicate large-scale thermal and magnetic instabilities. The cause of these instabilities and, more basically, the reason for their twenty-two year periodic variation is not yet understood. Other stars show even more striking examples of instability; stars which pulsate with periods of days or even hours; others which exhibit large, highly variable magnetic fields; and, finally, the novae and super-novae, which are subject to catastrophic explosions.

Interstellar Matter

The material between the stars has a composition similar to the stellar composition, in the form of individual atoms and radicals and small dust particles, or grains. The space density of this material is a few atoms per cubic centimetre and except near hot stars it has a kinetic temperature of about 100° K. In spite of the low density, the total mass of interstellar matter in the Milky Way is approximately equal to the total stellar mass. This material has a profound effect on stellar observations because its scattering reduces the intensity of starlight passing through it, and because it superposes interstellar absorption lines on stellar spectra. In addition, the material has a marked tendency to occur in clouds near hot, luminous stars, which themselves are often found in clusters. In these cases, the interstellar clouds are illuminated and become visible as reflection nebulae. If the nearby stars are hot enough to excite the gas, an emission nebula results, emitting energy primarily in the lines of hydrogen and of some of the trace constituents. In these nebular complexes the density may be as high as a thousand atoms per cubic centimetre, and the kinetic temperature is usually about 10,000° K. Knowledge of the interstellar medium has increased rapidly since the development of radio astronomy. Radio-frequency emission has been detected from the neutral hydrogen in the interstellar gas, and has proved to be a valuable tool in probing distant parts of the Galaxy. Thermal radio-frequency radiation has been observed from emission nebulae, and radio-frequency synchrotron radiation has been measured from nebular remnants of super-novae explosions. The polarization of starlight has indicated the existence of magnetic fields in the interstellar medium which may play an important role in the production of cosmic rays.

Star Clusters and Galaxies

Stars tend to occur in multiple systems of two to six stars and in clusters of tens to many thousands. The study of such clusters has been valuable because the members presumably have common origins and histories and thus present homogeneous populations suitable for statistical analysis. On a larger scale, stars are clustered into galaxies containing billions of members. In appearance, these galaxies range from the smaller systems, which are spherical, ellipsoidal or irregular, and composed of fainter stars and little interstellar gas, up to the massive, highly flattened spiral galaxies which show a great deal of complex structure. Our galaxy, the Milky Way, is an example of the latter type. It consists of a central spheroidal nucleus of stars, surrounded by a round stellar sheet, quite thin compared to its diameter. Within this sheet, the galactic plane, the brightest stars and most of the interstellar material are concentrated into spiral arms. The Sun is within such an arm. However, in addition to these stars, there is a second group of stars having different temperature-luminosity and velocity characteristics which are spherically distributed about the galactic nucleus. These so-called Population II stars are quite similar to the stellar populations of the smaller elliptical galaxies. It appears that spiral structure with its associated interstellar material and bright stars may be a superficial and rather recent phenomenon superposed on an older and more fundamental stellar population of which all galaxies are composed.

Stellar Evolution

With the possibility in mind that there are stars with different ages and histories, the differences between the temperature-luminosity diagrams of different groups of stars, and especially of different star clusters, may be interpreted as being due to age and evolutionary differences as well as to small variations in chemical composition. The presently available evidence points to the following picture of galactic and stellar evolution. The original material of the universe coalesced into discrete

globs or proto-galaxies and, in turn, stars and star clusters condensed out of these globs. After the initial period of star formation, those galaxies which had no excess material, or which lost their excess material through intergalaxy collisions, evolved into the elliptical galaxies. In the remainder, the excess material collapsed into flat sheets in which star formation has continued at a slower pace up to the present time. Star formation can occur when a local inhomogeneity in a dense interstellar nebula becomes large enough and dense enough to contract due to self-gravitation. The interior pressure and temperature eventually becomes sufficiently high to support thermonuclear reactions and the gas becomes self-luminous, after which radiation pressure prevents the accumulation of appreciable interstellar material. The size and luminosity of the new star are determined by the amount of material accumulated before energy production begins. Multiple star formation from a single cloud is common. In some cases, the nebular material remaining around a new star condenses into planets. Single stars not surrounded by planetary systems are probably rare. Stars consume themselves by an ever-accelerating process of converting hydrogen into helium until the hydrogen is exhausted. At this point the internal support of the star due to radiation pressure is removed and the main body collapses, while a tenuous outer atmosphere expands to tremendous proportions to preserve dynamic balance. The main body contracts until the central temperature and pressure become high enough to support the conversion of helium into heavier elements with an accompanying release of energy During this evolution the star may pass through phases of dynamic instability where pulsation occurs. Eventually the star has no more energy resources left to support its mass and an implosion occurs, producing a nova. The post-nova stellar core may then settle down into an extremely dense sub-luminous white dwarf star until it goes out completely.

Current Problems

The Sun

The Sun is the only star on which we can study small regions of the surface and atmosphere. For this reason, and because solar radiation profoundly affects the physical conditions in the Earth's atmosphere, the Sun is an object of prime importance for detailed study. To gain a better physical picture of the conditions in the undisturbed Sun, more accurate measurements are needed of the solar constant and of the energy distribution in the entire solar spectrum, not just in the region observable from the surface of the Earth. Also, particularly because of its effect on terrestrial conditions, a long term study of the disturbed Sun in all wavelengths, especially in very short optical wavelengths and in very long radio wavelengths is of great importance.

The causes and nature of the phenomena occurring in the solar atmosphere and their effects on physical conditions in interplanetary space are of vital importance in the climatology of the planets. Some basic problems involve the propagation of disturbances through the solar atmosphere, the role of convective transport of energy in this atmosphere and the origin, support and heating of the chromosphere and corona.

The Solar System

There are still many pertinent questions concerning the physical characteristics of the planets and the other constituents of interplanetary space. More information is required on the percentage concentration of oxygen, water vapour, and other important gases in planetary atmospheres, the physical properties of the planetary surfaces and the structure of planetary interiors. Since the maximum intensity of the thermal radiation from the planets occurs in the infra-red, it is obvious that studies in these wavelengths are important for deriving the physical characteristics of the planetary surfaces. The important band spectra from planetary atmospheres tend to occur in the infra-red also. In addition, even those absorptions in the region of the spectrum accessible from the Earth's surface are partially obscured by similar molecules in the terrestrial atmosphere. Finally, the information needed on the structure of planetary interiors can best be derived by studying the effects of these planets on nearby satellites should eventually prove particularly useful for this purpose.

An interesting question is that of the existence of a permanent interplanetary gas. If this exists, is it primarily the interstellar gas through which our solar system is moving or is it matter ejected from the Sun or part of the solar atmosphere? The existence of such a nebula would provide a laboratory for studying general nebular properties, and for studying at first hand a gaseous nebula surrounding a star. In addition, the existence of a solar nebula may also limit our study of nebulae elsewhere in the stellar system.

Stellar Physics

More accurate information is needed on fundamental quantities such as stellar masses, radii and luminosities. For stars much hotter or much cooler than the Sun, the luminosities must be extrapolated from the very small spectral region accessible from the surface of the Earth to the regions which contain the predominant energy output of these objects. In the field of stellar atmospheres, more information is needed on the relative importance of radioactive transfer as compared to the transfer of energy by mass motion and on the origin and effects of stellar rotation and magnetic fields. Important information on these problems is provided by the relative energy output in widely separated regions of the stellar spectrum. Our current knowledge of stellar composition, structure and evolutionary processes depends upon spectroscopic observations in a relatively limited region of the spectrum. It is obviously desirable to extend our observations over the entire electromagnetic spectrum. These observations are especially important for the hot stars which are in rapid evolution. Both their maximum energy output and the spectral lines

which are critical for studying the abundances of important elements in these stars are in the currently inaccessible ultra-violet.

Interstellar Medium

In the study of the interstellar medium, the question of the energy balance has been re-opened by recent rocket investigations which show more ultra-violet energy being released by radiative processes than had been previously supposed. Additional information is needed regarding the nature of interstellar grains, their absorption and scattering of starlight in a wide range of wavelengths, particularly in the infra-red, and their interaction with the interstellar magnetic fields. In studies of the interstellar gas, astronomers have been handicapped by the lack of observation in the ultra-violet portions of the spectra where the principal spectral lines of the interstellar gases lie. These data promise to supply vital information on the chemical composition, distribution relative to galactic features, and the mass motions and excitation processes which play an important role in the evolution of our galaxy.

Star Clusters and Galaxies

Star clusters, galaxies and clusters of galaxies constitute the large-scale building blocks of the universe. The role and mechanism of these associations remain questions basic to the solution of the origin and evolution of our universe. The individual properties of the star cluster and the galaxy such as mass distribution, mass-luminosity ratio, angular momentum, gas and dust concentration and energy balance are typical of the parameters needing study. At present we have little knowledge of the nature and density of the material in intergalactic space as observations in the visible spectrum have proved inconclusive. It is desirable to carry the observations into ultra-violet portions of the spectrum where higher absorption can be expected to greatly increase the sensitivity of these measurements. Current theories in cosmology depend strongly upon the correct interpretation of the red shift. It is desirable to determine if this red shift is a constant over the whole electromagnetic spectrum, and also if it is a linear function of distance. Since the red shift for very distant galaxies is sufficient to shift the normally observed spectral features into the unobservable infra-red, detailed studies of the ultra-violet region of nearby galaxies and the infra-red of very distant galaxies are essential to the detection of possible evolutionary effects during the billion or more years it has taken the light from the latter to reach the Earth.

PROGRAMME

Long Range

The great distances of astronomical objects outside of the solar system mean that they are both small in angular dimensions and apparently faint. Hence, for wavelengths shorter than one metre the objects require long periods of observation with large radiation collectors having good angular resolution and accurate pointing. Radio-astronomical observations in wavelengths beyond the ionospheric limit require extensive antennae arrays to achieve good resolution. Thus, until an observatory on the Moon is possible, experiments in this wavelength region will be limited to the Sun and to low resolution reconnaissance surveys. In the short-wave radio regions, astronomical sources are weak. It is possible that the development of large inflatable balloons will provide the necessary collecting area for observations in this region. To provide the necessary pointing accuracy and observing time for experiments in the infra-red, optical, ultra-violet and X-ray regions of the spectrum, development has begun on an orbiting stabilized platform. It will be possible to point this platform toward any point in the sky and to hold it in that direction for periods from a few minutes to an hour with sufficient accuracy to allow continued observations of individual celestial objects. The satellite will contain instruments of moderate size which can be completely controlled from the ground, thus providing a remotely operated observatory which can perform most of the functions of a ground-based observatory. Although the sky above the Earth's atmosphere will be dark, the presence of sunlight scattered within the vehicle itself may be disturbing. The eventual establishment of an astronomical observatory on the Moon will eliminate this difficulty, since the Moon itself can provide an effective shield against the sunlight. Moreover, the establishment of an observatory on the Moon will undoubtedly make feasible larger equipment than can be placed on a satellite-borne platform. The execution of these programmes will require not only the development of a stabilized platform and its pointing controls, but also specialized optical equipment and radiation receivers for particular wavelength regions, especially adapted for a particular programme, and improvements in telemetering techniques so that transmission to ground stations of spectroscopic data of adequate scope and resolution will be possible. For planetary studies, the planetary satellites and planetary probes planned for the atmospheres programme will also be useful for providing information on the surface conditions and interior structures of the planets.

Immediate

The immediate programme includes the exploration of the Moon, reconnaissance measurements in the ultra-violet region of the spectrum to determine the brightness and positions of interesting regions of the sky, preliminary testing of equipment and techniques to be used later on the stable platform, and studies of the Sun in the ultra-violet and X-ray region with pointing controls somewhat less stringent than those to be used for the stable platform. The reconnaissance will continue and extend to the southern sky the survey of the newly-discovered extended emissions in the far ultra-violet in order to determine the nature and sources of these emissions. Stellar photometry measurements will be made in the near and far ultra-violet spectral regions

to extend the magnitude systems to these wavelengths. Emphasis is being given to observations in the previously unexplored far ultra-violet and high energy gamma-ray spectral regions. Studies of the solar ultra-violet and X-ray spectra will include their long-term variations, line profiles, distribution across the disc, and the spectra of the coronal X-ray emissions. In addition, long wavelength radio receivers will be placed in satellites to study the brightness distribution of the sky in these wavelengths, the spectrum of the Sun and its variation, and the absorption of the Earth's ionosphere at various heights.

BIOSCIENCES

Objectives

To determine the effects on living terrestrial organisms of conditions in the Earth's upper atmosphere, in space, and in other planetary atmospheres. To determine the effects of flight through space on living organisms. To investigate the existence of life throughout the solar system, and to study in detail whatever extraterrestrial life forms exist.

Problems

The opportunity now exists to conduct fundamental life sciences research in satellites and space probes. In such research, conditions in space and conditions during flight through space enter as new experimental variables. Principal interest lies in the components of the space and spaceflight environment that are irrevocably different from the terrestrial, such as radiation and the altered gravity state. The former is qualitatively and quantitatively different from terrestrial radiation and looms as a far more important problem than originally thought. The latter offers the possibility of elucidating biological processes known to be effected by weight or apposition of one part against another, such as cell division and organogenesis. These and other areas of study could be carried out in satellites or space probes from which specimens under study could be recovered.

More specifically, fundamental experiments on living organisms in the satellite environment or in other types of space vehicles and stations should be conducted along the following general lines:—

Animal navigation and orientation.
Mitosis and embryology.
Plant morphogenesis.
Geotropic response of plants to altered gravitational fields.
Biological rhythms and cycles.
Altered gravitational effects on blood circulation in animals.
Vestibular physiology.
Neuropharmacology—effects of tranquilizers, motion sickness drugs, etc.
Effects of cosmic radiation.
Tolerance limits for combined stresses.
Physiological and psychological deterioration.
Effects of acceleration and deceleration.

There has been considerable speculation about the possibility of the existence of extraterrestrial life forms. The debate ranges from whether or not life exists on Mars and Venus, and if so, in what form, to whether or not spores and similar life forms can survive the rigours of interplanetary space. Investigations of these topics must for the most part await observations which can be made on direct samples and studied in space laboratories of the future. It is conceivable, however, that with proper and specialized instrumentation and remote sampling techniques it may be possible to obtain evidence of primitive or complex organic material without the presence of a scientist and a laboratory in the sample area. Elaborate instrumentation and the recovery of records, or advanced telemetering techniques could provide information about the nature of biochemicals on the planets.

Programme

The programme in biosciences is still being formulated. Immediate steps include a series of discussions with leading bioscientists to agree important initial lines of attack.

[Continued from page 238.

References

1. Briggs, M. H. and Revill, J. P., *J.B.I.S.*, in press.
2. Antoniadi, E. M., "La Planete Mars," Paris, Hermann et Cie.
3. Strughold, H., "The Green and Red Planet," Albuquerque, University of New Mexico Press, 1953.
4. Spitzer, L., in "The Atmospheres of the Earth and Planets," Kuiper, G. P. (ed.), Chicago, University of Chicago Press, 1952, p. 211.
5. Hutchinson, G. E., in "The Earth as a Planet," Kuiper, G. P. (ed.), Chicago, University of Chicago Press, 1954, p. 371.
6. Webb, W. A., "Mars, the New Frontier. Lowell's Hypothesis," San Francisco, Fearon Publishers, 1956.
7. Lowell, P., *Mon. Not. Roy. Astron. Soc.*, **57**, 148, 1897.
8. Slipher, V. M., *Publ. Astron. Soc. Pacific*, **36**, 261, 1924.
9. Tikhov, G. A., *Bull, Astron. Geodet. Soc. U.S.S.R.*, **1** (8), 8, 1947.
10. Millman, P. M., *Sky*, **3** (10), 10, 1939.
11. Kuiper, G. P., in "The Atmospheres of the Earth and Planets," Kuiper, G. P. (ed.), Chicago, University of Chicago Press, 1952, 306.
12. de Vaucouleurs, G., "Physics of the Planet Mars," Faber and Faber, 1954.
13. Slater, A. E., *Spaceflight*, **1**, 35, 1956.
14. Tikhov, G. A., *J. Brit. Astron. Assoc.*, **65**, 193, 1955.
15. McLaughlin, D. B., *The Observatory*, **74**, 167, 1954.
16. McLaughlin, D. B., *Publ. Astron. Soc. Pacific*, **66**, 161, 221, 1954.
17. Opik, E., *Irish Astronom. J.*, **1**, 45, 1950.
18. Sinton, W. M., *Astrophys. J.*, **126**, 231, 1957.
19. Sinton, W. M., *Bull. Lowell Obs.*, 1959.
20. Sinton, W. M., *Science*, **130**, 1234, 1959.
21. Kuiper, G. P., *Harvard Announcement Card*, 851. 1947.
22. Kuiper, G. P., in "Threshold of Space," Zelikoff, M. (ed.), New York, Pergamon, 1957.
23. Briggs, M. H., *The Observatory*, **79**, 20, 1959.
24. Dunham, T., *Publ. Astron. Soc. Pacific*, **45**, 200, 1933.
25. Urey, H. C., "The Planets," New Haven, Yale University Press, 1952, p. 152.
26. Kiess, C. C. and Corliss, C. H., *Sci. News Letter*, **75**, 229, 1959.
27. Heyden, F. J., Kiess, C. C. and Keiss, H. K., *Science*, **130**, 1195, 1959.

Atomic Generator for Spacecraft

A nuclear electrical generating system for space-vehicles is being developed by the Aerojet-General Corporation under an $8 million contract with the National Aeronautics and Space Administration. The reactor itself, known as the SNAP-8, is being developed under a separate contract to Atomics International, a division of North American Aviation, Inc., from the Atomic Energy Commission. A.E.C., which is responsible for the United States reactor programme, is working with N.A.S.A. on nuclear power and propulsion systems for various space applications.

Although N.A.S.A. has yet to place a contract for the spacecraft in which SNAP-8 is intended to operate, it is hoped that the entire system will be ready for launching within 5 years. SNAP is the shortened form of Systems for Nuclear Auxiliary Power; 8 is the design number. It is intended to generate 30,000 W.—enough electricity to supply ten average homes—and to remain in operation for at least a year without attention.

Major components are: (1) a nuclear reactor, and (2) a heat-to-electricity conversion system, similar in principle to conventional electricity generators. Total weight, including reactor and shield, will be about 1500 lb.

Function of the reactor will be to heat a closed system of pipes containing a liquid metal. These pipes will pass into a boiler through which a second system of pipes, containing mercury, also passes. The first "loop" of pipes will heat the second, vaporizing the mercury. In turn, the vaporized mercury will drive a turbo-generator to produce electricity.

After the mercury leaves the turbine, it will be routed through a series of tubes forming a radiator several hundred square feet in area. This will cool the mercury, reverting it to liquid form, whereupon the fluid will continue through the closed loop under pressure to repeat the cycle.

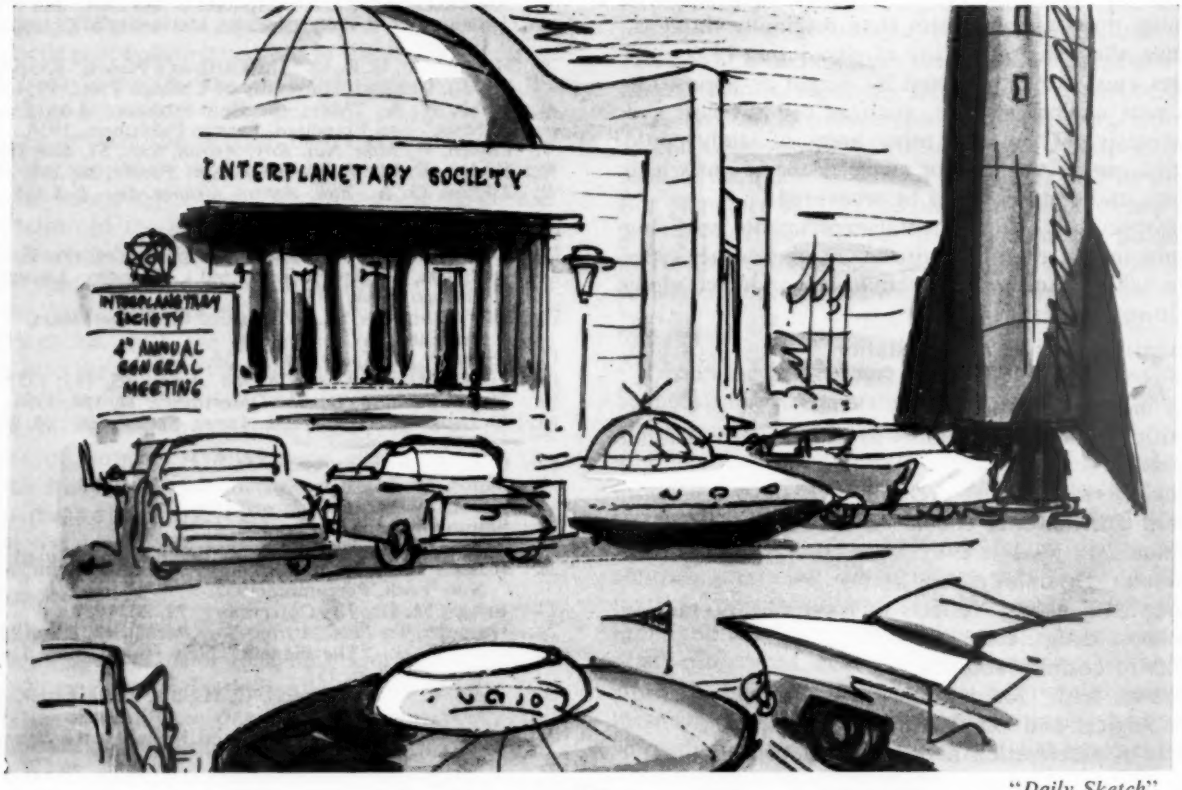
Preliminary estimates suggest that a prototype system could be launched into a nominal 300-mile orbit around the Earth in a satellite weighing several tons. The generating system would be turned on when the vehicle arrived in orbit. Eventually, a dual version of SNAP-8 using a single reactor to produce 60,000 W., could be put into orbit in a spacecraft weighing 15 tons or more. This would require the services of a multi-stage Saturn booster.

W W W

WANDLESIDE WARREN WIRE CO. LTD.

Are Specialists in the manufacture of Electric Wires and Cables, for **REALLY HIGH** TEMPERATURE APPLICATIONS for all Electronic Devices as used in Space Vehicles, Rockets, Guided Missiles, etc.

All enquiries to:—
106 GARRATT LANE, WANDSWORTH, LONDON, S.W.18
Tel: VANdyke 7544 Telegrams Wandleside London



"*Daily Sketch*"

ASTRONAUTICA ACTA

Official Journal of the
International Astronautical Federation

Published by Springer-Verlag of Vienna

Volume VI (1960) Price per year (6 issues), £3 11s. 6d. ($10), plus postage. Copies of **Volume V (1959)** are also obtainable at this price.

Volumes I (1955)—IV (1958) are still available; price per volume (4 issues), £3 2s. ($8.60) plus postage.

Members of the British Interplanetary Society or other Constituent Societies of the International Astronautical Federation are entitled to receive *Astronautica Acta* at a discount of 20% on the above prices. Orders and remittances should be sent to the British Interplanetary Society,
12, Bessborough Gardens, London, S.W.1.

THE BRITISH INTERPLANETARY SOCIETY

BENEVOLENT FUND

The Society's Benevolent Fund has been established as a means of alleviating distress caused to members or their dependents by disablement or bereavement, etc. Initially, any member of the Society of more than five years' standing (or his or her dependents) is eligible for assistance. Benefits from the fund are NOT restricted to members in the United Kingdom or British Commonwealth.

The Fund is administered by Trustees, who would be grateful if cases meriting consideration could be brought to their attention.

The initial target for the fund is £3,000, the sum received to date £910. Further contributions will be welcome. Remittances should be made payable to the B.I.S. Benevolent Fund, and should be sent to:

The Secretary,
12 Bessborough Gardens, London, S.W.1

CORPORATE MEMBERSHIP
OF THE
BRITISH INTERPLANETARY SOCIETY

★ **Corporate Membership** is a new grade of membership open to industrial, scientific, educational and other organizations.

★ **Privileges** of Corporate Membership include:

(*a*) Receipt of the Society's *Journal*, of *Spaceflight*, and of all other publications of the Society.
(*b*) The right to nominate five individuals who will receive the full benefits (including periodicals) appertaining to the grades of membership to which they respectively are elected.
(*c*) Use of the Society's library.
(*d*) The right to advertise in both the *Journal* and *Spaceflight* at 25% discount on the normal rates.
(*e*) Receipt of *Astronautical Acta* and of the technical papers presented at each congress of the International Astronautical Federation.
(*f*) The right to send representatives to attend all Society meetings and the Congress of the International Astronautical Federation.

★ **Fees.** The fee payable by a Corporate Member is £100 per annum.

★ **Present Corporate Members:** The first Corporate Members to be elected are:
AVIATION BRANCH, AIR B.P. LTD. and SUD-AVIATION.

★ **Further Particulars** are obtainable on application to:

THE SECRETARY, BRITISH INTERPLANETARY SOCIETY,
12 Bessborough Gardens, London, S.W.1.

Printed by W. Heffer and Sons, Ltd. Cambridge and Published by The British Interplanetary Society, 12, Bessborough Gardens, London, S.W.1.
Advertisement enquiries to: Cheiron Press Ltd., 3, Cork Street, London, W.1. (REGent 5301)

THE BRITISH INTERPLANETARY SOCIETY

THE BRITISH INTERPLANETARY SOCIETY was founded in 1933 to promote the development of astronautics—interplanetary exploration and communication—by the study of rocket engineering, space medicine, astronomy, navigation, astrionics and other associated sciences. Its membership is international and includes most workers prominent in these fields.

The main work of the Society consists in the publication of two periodicals (free to all members); in the publication of books and monographs; and the organization of scientific and technical meetings. In addition to symposia and meetings at which original research papers are presented, lectures, exhibitions, visits to research establishments and film shows are held to explain to the lay public the progress that is being made in astronautics and the ultimate implications to human society of the crossing of space.

PRIVILEGES OF MEMBERSHIP

All members of the Society are entitled to the following privileges:

(*a*) To receive copies of the *Journal* (six issues per year), which contains research papers, reports of lectures, news items, announcements, reviews and abstracts of all important publications on astronautical subjects.

(*b*) To receive copies of *Spaceflight*, a quarterly non-technical magazine, and other publications issued from time to time.

(*c*) To attend all lectures, meetings, symposia, exhibitions, and film shows arranged by the Society.

GRADES OF MEMBERSHIP

There are four grades of membership of the Society: Fellowship, Associate Fellowship, Senior Membership and Membership.

Fellowship

The general requirements for Fellowship are any one of the following:

(*a*) A recognized University degree in Science, Mathematics, Engineering or Medicine, *plus* five years' relevant scientific, industrial or other professional experience.

(*b*) Corporate Membership of a recognized professional Institution.

(*c*) Considerable contributions to the development of astronautics.

Associate Fellowship

To be eligible for admission as an Associate Fellow, an applicant shall possess at least one of the following qualifications:

(*a*) A recognized University degree in Science, Mathematics, Engineering, or Medicine.

(*b*) Graduateship of a recognized professional institution.

(*c*) Higher National Certificate, or an equivalent.

(*d*) An examination qualification equivalent to Inter. B.Sc. or Ordinary National Certificate, *plus* five years' relevant scientific or industrial experience.

Applicants for election to Associate Fellowship under Clause (*d*) above must not be less than 25 years of age. Applicants for election under other clauses must be over the age of 21 years.

Senior Membership

Applicants for this grade must have been members of the Society for a period of seven years.

Membership

No technical or other qualification is required for membership, as this grade is particularly intended for the large body of persons who realize the possibilities of astronautics and wish to keep in touch with current developments. There are no age limits.

FEES

Subscriptions are payable on 1 January in each year, at the following rates:

Fellows, Associate Fellows and Senior Members, £3 3s. 0d.; Members, £2 2s. 0d. (under 21, £1 11s. 6d.).

An entrance fee of 10s. 6d. is also payable with all applications.

1212